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Risø National Laboratory, Roskilde, Denmark
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Abstract Selected activities in the Environmental Science and Technology Department during 1991 are presented. The research approach in the department is predominantly experimental. The research topics emphasized are introduced and reviewed in chapters one to seven: 1. Introduction, 2. The Atmosphere, 3. Plant Genetics and Resistance Biology, 4. Plant Nutrition, 5. Geochemistry, 6. Ecology, 7. Other activities. The Department's contribution to national and international collaborative research programmes is presented together with information about large facilities managed and used by the department. Information about the department's education and training activities are included in the annual report along with lists of publications, publications in press, lectures and poster presentations. Further, names of the scientific and technical staff members, Ph.D. students and visiting scientists are listed.

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Contents

1 Introduction

1.1 Research Objectives

The department aspires to develop a sound scientific basis for future technology and methods in industrial and agricultural production. Through basic and strategic research, the department endeavours to develop new ideas for industrial and agricultural production, exerting less stress and strain on the environment, and with less energy consumption.

The main research topics are:

The atmospheric environment

Plant genetics and resistance biology

Plant Nutrition

Geochemistry and recycling of industrial waste

Ecology and mineral cycling

The expert domain of the department contains a wide range of subjects including atmospheric chemistry, chemical reactivity, geochemistry, biogeochemistry, geochemical modelling, hydrochemistry, analytical chemistry, organic synthesis, marine and terrestrial ecology, radioecology, trace metal ecology, plant nutrition, biological interactions, plant molecular biology, plant pathogens, plant genetics and cytogenetics, and plant breeding.

1.2 The Atmospheric Environment

The atmospheric research aims to establish a solid scientific basis for rational legislative measures to reduce the industrial impact on the atmosphere of air pollution.

The research includes basic atmospheric chemistry, gas kinetics, transport and dispersion of air pollutants, especially nitrogen compounds and carbohydrates, VOCs, PANs, PAHs, CFCs, HCFCs and HFCs.

The department's atmospheric research involves three aspects. Firstly, determination of the sources of air pollution. Secondly, determination of primary and secondary pollutants in rural areas to assess the effects of atmospheric processes. Thirdly, laboratory studies of chemical mechanisms in the gas phase, and in the liquid phase of relevance to atmospheric chemistry.

Atmospheric chemistry influences the climate, and the deposition of airborne pollutants can give rise to direct injuries to plants and indirect damage through bio-accumulation.

To model and predict changes in the atmospheric composition, a better understanding of the chemical processes in the atmosphere is needed. In order to make the research results operative in the environmental policy making, the critical loads need to be established for natural and semi-natural ecosystems.

1.3 Plant Genetics and Resistance Biology

In this field of research, the department aims to develop the scientific basis for breeding crop plants with new and improved resistance to diseases and with improved nutrient efficiency.

Growing plants, highly resistant to diseases with less nutrient demand, will reduce a number of environmental problems related to high yield plant production.

Exploitation of genetic variability, related to traits of economic and environmental importance in crop improvement, can be greatly facilitated by the use of marker-assisted selection; a large part of the research effort within plant biology and genetics is devoted to the application of genetic markers. The research relies on the command of a number of techniques such as RFLP, RAPD, PCR, genetic analysis of quantitative traits, cytogenetic techniques, enzyme electrophoresis, *in situ* hybridization and *in vitro* culture.

An understanding of the interaction between plant species, as well as the interaction between plants and pathogens, can be enhanced by identification of changes in genetic variability under different environmental conditions. Three different aspects of plant pathogen interactions are studied. First, chemical defence compounds such as callose, peroxidase and chitinase are studied in barley and rapeseed together with various phenolic compounds in barley. Second, genetic resources of species- specific resistance in barley to powdery mildew and leaf stripe disease are studied. Third, we try to elucidate the very specific interaction based on gene-to-gene recognition in the barley powdery mildew system.

In population biology, experiments and theoretical studies of interactions between populations are important in understanding the systems. The research is devoted to interactions between crop plants and weeds, and between crop plants and their pathogens. The possible exchange of genes between related species and the competitive abilities of crop plants are studied together with the risk of gene flow from genetically modified cultivated plants into wild natural relatives and the effect of new genes transferred to natural plants. This type of research is needed to evaluate the risk to the environment from transgenic varieties.

1.4 Plant Nutrition

The aim of the plant nutrition research is to provide a solid scientific basis for a better understanding of root-microbe symbiosis in relation to carbon, nitrogen and phosphorus, and to provide scientific information about the turn-over of organic nitrogen.

The research emphasizes biological, physiological, biochemical, chemical and physical processes involved in the transfer of plant nutrients, especially nitrogen and phosphorus through the Soil-Plant-Air-Continuum.

The department's plant nutrition research involves five aspects.

Firstly, research on symbiotic nitrogen fixation, which highlights the exchange of compounds between the host plant and the microsymbiont across the membrane interface. Secondly, studies of the interaction between VA-mychorrhiza, plant roots and the rhizosphere. Thirdly, studies on turn-over of nitrogen from crop residues and farmyard manure by use of ^{15}N-labelled plant material and farmyard manure. Fourthly, biological transfer of nitrogen from legumes to non-legumes. Fifthly, the effect of air pollution with ammonia, especially on Norway spruce.

The research is essential to the future development of new plant production techniques based on biological fixed nitrogen, and with highly effective assimilation and recycling of nutrients in order to reduce the possibility for loss of plant nutrients due to surface run off, losses of nutrients to the atmosphere or leakage to the ground water.

1.5 Geochemistry and Recycling of Industrial Waste

In this area, the department has contributed to the scientific development of the wet oxidation technique. New methods are developed for the conditioning and treatment of soil, sludge, sewage and other waste products from industrial productions contaminated with heavy metals.

Existing toxic waste deposits have created severe environmental problems in industrialized countries, and the department aims to develop methods to repress the uncontrolled release of toxic material from waste deposits.

In geochemical modelling, the JENSEN program has successfully been applied to predict the possible geochemical transformations to be expected, when foreign minerals are added to polluted waters. The research also aims to model the migration of heavy metals and nutrients, and predicts the fate of deposits in geological structures and in soils.

In marine geochemistry, rare and precious metals were studied in marine sediments, as well as the ferromanganese phase, from the Pacific. Ferromanganese crusts and nodules from New Zealand were analyzed for rare elements. Radiometric methods for inspection of the sea floor and a new radiometric sonde are being developed for exploring marine sediment resources.

In analytical chemistry, an electrothermal vaporisation unit has been linked to the ICP/MS. The instrumentation has been expanded with new HPLC equipment and the installation of a new GC/MS; a HPLC/MS is planned in 1992. New analytical methods for trace metal analysis and stable isotope analysis are being developed.

The department is involved in several commercial organic synthetic projects, ranging from the preparation of isotopically labelled compounds, to the attachment of supramolecular units to both natural macromolecules and polymer surfaces. At present the group is synthesising catalytically active metal complexes, bonded to electroconducting organic polymers.

1.6 Ecology and Mineral Cycling

Ecological and mineral cycling research aims to improve the scientific basis and understanding of the impacts of environmental pollution on marine and terrestrial ecosystems with emphasise on natural and semi-natural ecosystems. Further, the research aims to establish better knowledge about transport and the faith of pollutants by use of radionucleides and tracemetal techniques.

Ecological halflives of radioactive contamination of terrestrial environments by fallout from the nuclear weapons testing in the atmosphere and regional fallout from the Chernobyl accident are studied in the Danish and Faroese environment.

The influence of plant variety on root uptake of radiocaesium is studied because the long term consequence for agricultural ecosystems of radioactive contamination depends on the transfer of radionucleides from the soils via roots to the above ground biomass.

Radioactive tracer techniques are used in projects on metal toxicity to fish and Baltic mussels as bioindicators for marine monitoring programmes for radionuclides and heavy metals.

The Greenland Sea project aims to explain the role of the Greenland Sea in the World Ocean Circulation making use of radioactive tracers ^{137}Cs and ^{134}Cs from the Chernobyl accident, and ^{99}Tc from Sellafield and La Hague.

The Ecology section also develops strategies and techniques for decontaminating areas contaminated by radioactivity. Different strategies and techniques have been tested in Gävle, Sweden and a "skim and burial" plough has been developed for burial of the 5 cm contaminated top-layer in agricultural areas.

The research depends on concepts and techniques from radio-ecology. Concepts of environmental dosimetry and critical loads for ecosystems are developed together with techniques for evaluating ecotoxicology in marine and terrestrial ecosystems.

1.7 The RIMI Field Station

Riso's Integrated Environmental Project (RIMI) is an interdisciplinary projet studying pathways, processes and effects on terrestrial ecosystems of nitrogen compounds derived from human activities.

RIMI is managed by the Ecology section and involves scientists from the Environmental Science and Technology Department, as well as scientists from the Meteorology and Wind Energy Department and the Optics and Fluid Dynamics Department at Riso.

The RIMI station serves as a reference station for air pollution monitoring in Copenhagen by the National Environmental Research Institute. The RIMI station is also used in the Danish EUROTRACH-TOR project.

1.8 The Experimental Farm, Dyskærgaard

Dyskærgaard has 120 hectares of arable land, and is managed by the Plant Biology section. The experimental farm is partly used for scientific field experiments, and partly for grain and beef production.

During the growing season, a herd of Hereford cattle graze the sea-shore meadows and salt marshes along Roskilde Fjord for nature management purposes.

In 1991 it was planned to implement Computer Aided Farming (CAF) techniques in the management of Dyskærgaard from 1992. CAF includes the most advanced technology for differentiated, on demand, fertilizer application, and differentiated, on demand, use of crop protection chemicals.

1.9 Organisation

The Environmental Science and Technology Department was formed during the reorganization of Risø National Laboratory in March 1990, and includes the former Agricultural Research Department, the former Chemistry Department in part, and the Ecology section from the former Ecology and Health Physics Department.

The Environmental Science and Technology Department includes approximately 135 scientific and technical staff members, and the department is organized into four sections with Dr Anne Jensen as Department Head.

1. Ecology Section.
   Head: Dr Asker Aarkrog

2. Chemical Reactivity Section.
   Head: Dr Ole John Nielsen

3. Chemistry Section.
   Head: Dr Vagn Gundersen

4. Plant Biology Section.

   Head of Plant Nutrition:
   Dr Gunnar Gissel Nielsen

   Head of Plant Genetics and Resistance Biology: *Dr Hanne Østergård.*

2. The Atmospheric Environment

2.1 Introduction

The effect of human activities on the global atmosphere has become evident during the last decades. For example, the tropospheric ozone concentrations have increased by a factor of three in remote areas and photochemical smog can be observed very long distances away from populated areas. An understanding of atmospheric changes requires a detailed characterization of the composition of the atmosphere. The department's atmospheric research has three aspects. The first is the determination of the sources of air pollutants. The second is the determination of primary and secondary pollutants in rural areas to assess the influence of atmospheric processes. The third is the laboratory investigation of chemical mechanisms in the gas and liquid phase, relevant to atmospheric chemistry.

2.2 The Gas Phase

CFC Substitutes

The loss of stratospheric ozone over the Antarctic in the early austral spring, stresses the importance of the atmospheric chemistry of halogenated compounds. Field observations, combined with many experimental measurements of the kinetics and mechanisms of the atmospheric reactions of key halogen-containing species, show that the release of man-made chlorofluorocarbons significantly perturbs the earth's atmosphere. These observations confirm the hypothesis of Rowland and Molina (1974), that release of large amounts of these compounds would significantly reduce the levels of stratospheric ozone. This has led to an international agreement to stop CFC production and to find replacement compounds. Hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) are likely CFC substitutes for a number of uses. HCFCs and HFCs contain one or more hydrogen atoms, thereby providing a point of attack for the hydroxyl radicals to initiate oxidation of these compounds in the lower atmosphere before they reach the stratosphere.

CH_3CHF_2 (HFC-152a) and $CHCl_2CF_3$ (HCFC-123) are two important compounds which have been proposed as alternatives to CFCs. Atmospheric oxidation of these compounds in the lower atmosphere is initiated by OH radical attack to generate the corresponding halogenated alkyl radicals:

$$CH_3CHF_2 + OH \rightarrow CH_3CF_2/CH_2CHF_2 + H_2O$$

$$CHCl_2CF_3 + OH \rightarrow CCl_2CF_3 + H_2O$$

Considering the importance of these reactions, it is surprising that, when this study was initiated, there were only a few studies published on the reaction of OH radicals with these compounds.

The rate constants for the reaction of OH radicals with CH_3CHF_2 (HFC-152a) and $CHCl_2CF_3$ (HCFC-123) were determined over the temperature range 295-388 K. All the measurements of OH rate constants were carried out using pulse radiolysis combined with kinetic spectroscopy and the results have been published (Nielsen, 9.1).

Halogenated Organic Compound in the Troposphere

1991 was the second year of a STEP project involving 9 European laboratories concerned with the kinetics and mechanisms of oxidation of chlorine - and bromine - containing compounds, under atmospheric conditions. It is the aim of this study to determine the tropospheric sinks for these halogenated compounds in order to provide a basis for the calculation of the ozone depletion potential of released halogenated species. Part of this work, concerning the spectra and kinetics of peroxy radicals, is being performed in collaboration with Dr. T. Wallington, Ford Motor Co., USA. Several CFC replacement compounds were investigated. The work on the peroxy radicals of HCFC-141b ($CFCl_2CH_2O_2$) and HCFC-142b ($CF_2ClCH_2O_2$) was finished and published (Wallington and Nielsen a, 9.1).

HFC-134a (1.1.1.2-tetrafluoroethane) is one of the potential substitutes for CFC-12 in air-conditioning systems. Following release, HFC-134a will react with OH radicals in the lower atmosphere to produce an alkyl radical which will, in turn, react with O_2 to give a peroxy radical;

$$CF_3CFH_2 + OH \rightarrow CF_3CFH + H_2O$$

$$CF_3CFH + O_2 + M \rightarrow CF_3CFHO_2 + M$$

The atmospheric fate of the peroxy radical CF_3CFHO_2 is uncertain. Recently, concern has been expressed that this peroxy radical would react with NO to produce an alkoxy radical, possibly leading to the formation of trifluoro-acetic acid. Soil bacteria might then metabolize trifluoroacetic acid to produce monofluoroace-tic acid - a potent mammalian toxin. To address this issue, the atmospheric chemistry of the peroxy radical derived from HFC-134a, needs to be understood.

Most kinetic studies of peroxy radicals rely on monitoring their strong absorption in the UV. Hence, the first step was to investigate the UV absorption spectrum of CF_3CFHO_2, and then to measure the kinetics of the reaction of CF_3CFHO_2 with NO.

The measured cross section at 220 nm was: $\sigma_{CF_3CHFO_2}(220\ nm) = (5.34 \pm 1.08) \times 10^{-18}$ cm^2 mol^{-1}. The rate constant for the reaction of CF_3CFHO_2 radicals with NO was then determined to be $(1.28 \pm 0.36) \times 10^{-11}$ cm^3 mol^{-1} s^{-1}. As part of this work, the rate constant for the reaction of F atoms with CF_3CFH_2 was measured and found to be $(3.6 \pm 0.9) \times 10^{-12}$ cm^3 molecules^{-1} s^{-1} at 298K. The results have been published (Wallington and Nielsen b, 9.1).

Bromine is also engaged in catalytic destruction of ozone in a similar cycle to that of chlorine. Indeed on a per molecule basis, bromine is a more efficient catalyst than chlorine in removing ozone. Little is known about the sources of different bromine compounds. Natural sources include biological activity in the oceans and volcanic activity. Bromine-containing compounds are used for a variety of purposes; fumigants, fire-fighting agents, anaesthetics, etc. The atmospheric lifetimes of the various bromine compounds differ substantially, because of differences in rates of reaction with hydroxyl radicals and photolytic destruction rates. It has been suggested that one of the dominant sources of bromine in the atmosphere is methyl bromide, CH_3Br. Data also suggest that the major part of emitted CH_3Br is of anthropogenic origin. Because the absorption spectrum of CH_3Br has insignificant overlap with the region of the tropospheric solar flux, CH_3Br is mostly removed from the atmosphere by reaction with OH radicals. Atmospheric oxidation of methyl bromide in the lower atmosphere is initiated by OH radical attack to generate bromomethyl peroxy radicals. The products of the oxidation of methyl bromide then depends on the fate of the CH_2BrO_2 radicals.

The pulse radiolysis technique was used to measure the UV absorption spectra and self-reaction kinetics of the CH_2Br and CH_2BrO_2 radicals. As an aid in the interpretation of the kinetic data, additional experiments were performed to investigate the products of the self-reaction of CH_2BrO_2 radicals using an FTIR spectrometer coupled to an atmospheric reactor (at Ford Motor Co.). Both the recorded spectrum (see figure 2.1.) and the obtained self-reaction rate constant were very surprising. The observed rate of the self-reaction of bromomethyl peroxy radicals in the present work is extremely rapid; i.e., approximately 100 times faster than that of CH_3O_2, and 10 times faster than those of CH_2FO_2, and CH_2ClO_2. While the exact mechanism by which this occurs remains uncertain, the enhanced reactivity of bromomethyl peroxy radicals presumably reflects a stabilization of the transition state by the presence of the bromine atom. Further studies on the temperature and pressure dependence of this reaction are needed. The results obtained so far have been published (Nielsen *et al.* a, 9.1).

Organonitrogen and Sulphur Atmospheric Transformations

In the final year of our four-year CEC-funded collaboration with University College Dublin, we have continued our investigations of the reactions of OH radicals and Cl atoms with a wide variety of compounds. Two series of organonitrogen compounds were investigated: n-alkyl nitrates and n-alkyl nitrites.

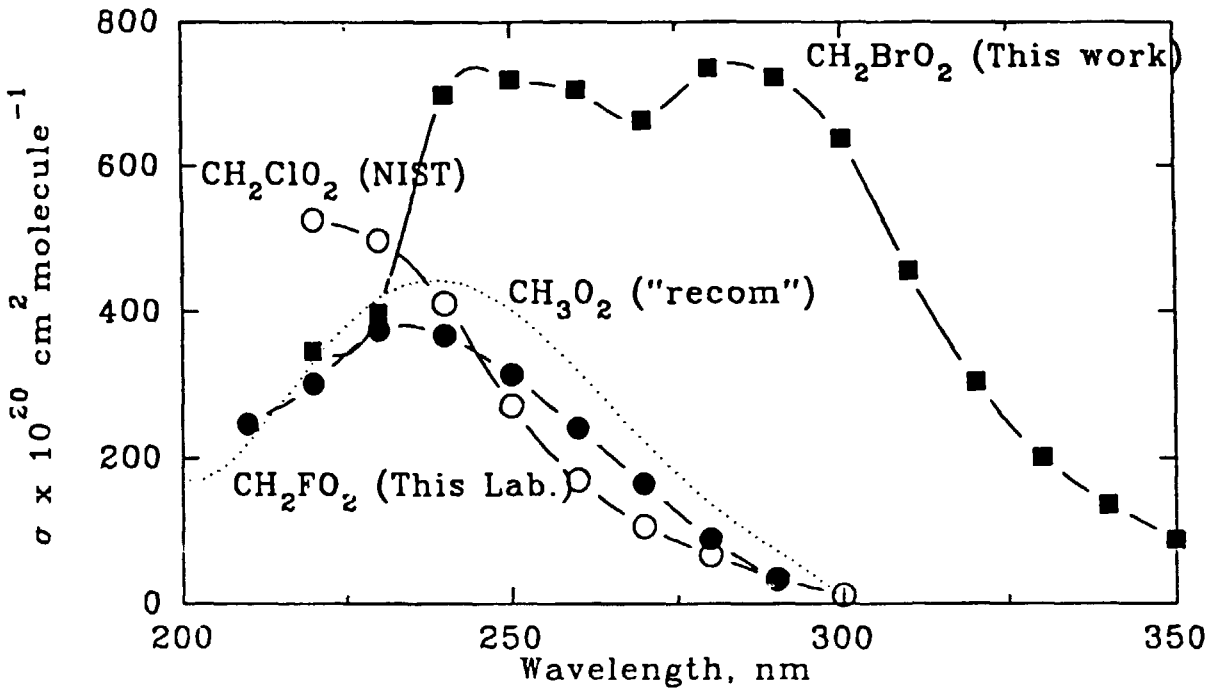

Figure 2.1. The observed UV-absorption spectrum of CH_2BrO_2 obtained at Risø compared with those of CH_3O_2 (recommended), $CH_2ClO)_2$ (from National Institute of Standrads and Technology) and CH_2FO_2 (also from Risø).

The atmospheric lifetimes of the n-alkyl nitrates, due to loss by reaction with OH radicals, can be calculated from the rate constant data determined . . this study. Assuming a tropospheric concentration of 1 x 10^6 molecules cm^{-3} for the OH radical, the relatively low reactivities of the nitrates give lifetimes in the range of 30 days for CH_3ONO_2 to 3 days for $n\text{-}C_5H_{11}ONO_2$. An estimate of the photodissociative lifetime for CH_3ONO_2 of approximately 5 days, based on the removal by reaction with OH radicals, has been reported in the lower troposphere. Absorption cross-section data were used in these calculations. This estimate is based on the quantum yield for photo-decomposition of unity and is hence a lower limit. Thus the alkyl nitrates may act as temporary sinks for nitrogen in the troposphere and become important in long-range transport of odd nitrogen (Nielsen *et al.* b, 9.1).

In the case of the n-alkyl nitrites, the atmospheric lifetimes, due to loss by reaction with OH radicals, can be estimated from the rate constant data determined in this work. Assuming a tropospheric concentration of 1 x 10^6 molecules cm^{-3} for OH radicals in moderately polluted atmospheres, the rate constant data give lifetimes of about 30 days for CH_3ONO to around 2 days for $n\text{-}C_5H_{11}ONO$. A photodissociative lifetime for CH_3ONO of approximately 2 min was calculated. The lifetime is almost independent of altitude, since the absorption spectrum of CH_3ONO extends into the visible region, where the solar flux intensities are strong and nearly constant with altitude. This estimate is based on a quantum yield for photodecomposition of unity and is hence a lower limit. The available kinetic and photochemical data indicate that the atmospheric lifetimes of alkyl nitrites will be dominated by their photolysis rates and that they will be rapidly removed during daylight hours (Nielsen *et al.* c, 9.1).

Recently, much interest has centred on the role of natural organic sulphur compounds in atmospheric sulphur chemistry. The CH_3S

radical, and possibly the CH_2SH radical to a lesser extent, are important intermediates in the oxidation of the naturally occurring sulphur species in the atmosphere. In collaboration with Dr. C. Anastasi's group at University of York (UK) we have investigated the UV absorption spectra of CH_3S and CH_2SH radicals. The results have been published (Anastasi *et al.* 9.1).

Oxidation of Aromatics

The tropospheric oxidation of benzene and other aromatics is initiated by reactions with OH radicals. This has been studied in an EEC-project (STEP-0007-C). Benzene reacts reversibly giving an adduct $OH + C_6H_6 = HO-C_6H_6$. In order to study the subsequent reactions, we recorded the UV-absorption spectrum of $HO-C_6H_6$ which has a maximum at 280 nm. The kinetics of the reaction $HO-C_6H_6 + O_2$ --> products were studied by monitoring the transient absorption of $HO-C_6H_6$ at 280 nm in the presence of varying amounts of oxygen. The reaction is very slow and we have estimated an upper limit for the rate constant of $k(HO-C_6H_6 + O_2)_{max} = 2 \times 10^{-14}$ cm^3 mol^{-1} s^{-1} at T = 298 K. The reaction with NO_2 was found to be much faster, $k(HO-C_6H_6 + NO_2) = 2.5 \times 10^{-11}$ cm^3 mol^{-1} s^{-1}. The reaction with oxygen, however, is still thought to be the most important process in the tropospheric oxidation of benzene. Work is in progress to determine the reaction products, and the reaction $HO-C_6H_6 + O_2$ --> $HO_2 + C_6H_5OH$ would appear to be the most important channel under atmospheric conditions. Similar experimental work has been carried out with toluene, where the reaction with hydroxyl radicals was found to proceed via two different channels, (a) $HO + C_6H_5CH_3$ --> $H_2O + C_6H_5CH_2$; (abstraction-channel) and (b) $OH + C_6H_5CH_3$ --> $HO-C_6H_5CH_3$; (addition-channel). The ultraviolet spectra of $C_6H_5CH_2$ and $HO-C_6H_5CH_3$ were recorded in the range of 210-300 nm and work is in progress to determine the branching ratio, i.e. the ratio of the rate constants k_a/k_b.

Preliminary studies of the decay rates of these radicals in the presence of oxygen showed that the reaction $C_6H_5CH_2 + O_2$ --> products is fast, while $HO-C_6H_5CH_3$ reacted much more slowly with oxygen, as in the case of $HO-C_6H_6$.

2.3 The Liquid Phase

Ozone is an important species in the aqueous oxidation processes in the atmosphere. It is, therefore, important to understand the O_3 decomposition mechanism in the aqueous phase. This study has shown that the initiation reaction in acidic solution is different from that in alkaline solution. In acidic solution, the initiation of the chain decomposition of ozone must be ascribed to the ozone dissociation/recombination reaction. The creation of chain-propagating radicals (OH and HO_2) probably proceeds via a reaction with water in a heterogenous process on the surface of the reaction vessel. The results from a study on the effect of O_3 concentration, oxygen, pH, temperature, vis-light and isotopic oxygen exchange (Sehested *et al.* 9.1), clearly demonstrate that the O_3 decomposition is associated with the dissociation of the O_3 molecule. To obtain a better understanding of the initiation process, acetic acid was employed as a radical scavenger. In the study of concentration effects, pH, temperature and H_2O_2 formation and consumption, the rate of the initiation reaction was determined to $k = 3.0 \times 10^{-6}$ s^{-1} at 31 °C and the activation energy to 82.5 kJ mol^{-1}. From the same system, a rate constant for the reaction of ozone with undissociated hydrogen peroxide was found to be 0.0065 dm^3 mol^{-1} s^{-1} at 31 °C. Further study of the reaction of O_3 with H_2O_2 indicates that both initiation and termination of the radical chain are surface reactions.

The rates of the oxidation reactions of ferrous compounds with ozone were measured in acidic solution by a stopped-flow technique. An intermediate complex, FeO^{2+} (formally FeIV) was found. Several rate constants were determined, and a mechanism for the disappearance of the complex, involving OH and HO_2 radicals, has been suggested. This mechanism is supported by computer simulations of all the results obtained. An article has been submitted to Inorganic Chemistry.

The SO_4^- and NO_3 radicals are important oxidizing agents in the aqueous phase of the atmosphere. SO_4^- is an intermediate in the radical chain oxidation of S(IV) to S(VI) and at night-time, NO_3 is the main oxidative radical in the gas phase and may diffuse into the aqueous phase. The SO_4^- is known to react with NO_3^- to form NO_3 with a rather low rate, $k = 5 \times 10^4$ M s^{-1}, but our experiments show that it reacts with HNO_3 at a much higher rate, also forming NO_3. On the other hand, NO_3 reacts with HSO_4^- reforming the SO_4^- radical and an equilibrium between SO_4^- and NO_3 is obtained. From experiments with mixtures of H_2SO_4 and HNO_3 an equilibrium constant of $K = 1.3 \times 10^3$ was measured. The forward reaction ($SO_4^- + HNO_3$) is of the order of 1×10^7 dm^3 mol^{-1} s^{-1}, and an article has been submitted for publication.

The rate constant of the reaction $SO_4^- + OH$ was determined in photolysis and radiolysis of SO_4F^- solutions, $k = 1.0 \times 10^{10}$ dm^3 mol^{-1} s^{-1}, (Kläning *et al.* 9.1). Several other rate constants for SO_4^- reactions with H, O_2^-, HO_2, $S_2O_8^{2-}$, and $S_2O_8^{2-}$ reactions with H and O_2^-/HO_2 were determined, employing our high pressure technique. Also using high pressures (150 atm), rate constants for the NO_3 radical reactions with NO_2, HO_2, H_2O_2 and formaldehyde were measured.

In the photolysis of an aqueous ClO_3^- solution, it is found that the primary process $ClO_3^- \xrightarrow{h\nu} ClO^- + O_2$ is the result of a cage-back reaction of the primary process $ClO_3^- \xrightarrow{h\nu} ClO_2 + O^-$. The ratio of the yields of ClO^- and ClO_3^- in the reaction $ClO_2 + O^-$, determined in γ-radiolysis of ClO_2 solutions at varying pH, equals the ratio between the quantum yield of O_2 formation and the quantum yield of ClO_3^- returning to the ground state after photolysis of ClO_3^-. This is taken as evidence for the cage-back reaction (Kläning and Sehested, 9.1). This work is carried out in collaboration with Århus University.

The work on high-temperature high-pressure aqueous radical chemistry continues by studying the reactions H + OH, OH + OH, e_{aq}^- + OH, e_{aq}^- + H, e_{aq}^- + H_2O_2 and Fe^{2+} + H_2O_2. The purpose is to determine the rate constants, activation energies and reaction mechanism at a temperature of 300 °C and pressures up to 15 MPa. Computer simulations of the reaction mechanism were performed to determine the rate constants and activation energies. An article on $Fe^{2+} + H_2O_2$ has been submitted for publication. This work is carried out in collaboration with Studsvik Energiteknik AB, Sweden.

Kinetics of reaction of primary water radicals e_{aq}^-, H, OH, and O^- with: 2-pyridinecarboxylic acid, 4-pyridinecarboxylic acid, 2,6-pyridinedicarboxylic acid, 3,5-pyridinedicarboxylic acid, as well as spectral and kinetic characteristics of transients thus formed, were obtained in a pulse radiolysis study (Solar *et al.* 9.1). An interesting feature, observed only in acid solutions, was the formation of two distinct products in reaction with the H atom, namely H-adduct to the pyridine ring and pyridynyl radical. In the case of 3,5-pyridinedicarboxylic acid, an intramolecular transformation of the ring adduct into the corresponding pyridinyl radical was observed.

This investigation was followed by a similar study of methyl substituted pyridines: 3-methylpyridine, 3,5-dimethylpyridine, 2,6-dimethylpyridine and 2,4,6-trimethylpyridine. It was found that the reaction kinetics, as well as spectra of the transients, are dependent of the protonation of ring nitrogen. The pKa values of OH-adducts were found. As the absorption spectra of the respective transients fall beyond the accessible range, the question as to the occurrence and extent of direct H-abstraction from the methyl groups remains unresolved. This project is carried out in collaboration with the University of Vienna, Austria.

Pulse radiolysis studies of intramolecular electron transfer in proline-bridged peptides Trp(Pro)nTyr was extended for n=4 and n=5 with the tryptophan terminal in both L- and D- form. Also cyclic peptides, with proline and glycine units between tryptophan and tyrosine, were studied. The rate constants were measured over a 10-55 °C range and activation parameters obtained. Significant influence of pH and optical isomerism on the intramolecular electron transfer rate was found in these systems.

The study of intramolecular electron transfer in HEW-lysozyme continued, in order to establish which of the Trp/Tyr pairs is respon-

sible for the azide radical-induced Trp/N$^{\bullet}$ → Tyr/O$^{\bullet}$ transformation. For this purpose, the effect of temperature, substrate (triacetylochitotriose) binding and conversion of particular tryptophan (Trp-62) by ozonation were applied. The obtained results indicate that Trp-62 and Tyr-53 are mainly involved. This work is carried out in collaboration with the Polish Academy of Sciences.

2.4 Field Atmospheric Chemistry

Tropospheric Ozone Research (TOR)

The DCAR-TOR (Danish Center of Atmospheric Research) project is a part of the European joint project EUROTRAC-TOR and is performed in collaboration between the Section of Chemistry and the National Environmental Research Institute. The project coordination is carried out by the Chemistry Section.

The Danish TOR measurements began in 1991 and include continuous measurements of NO_2, SO_2 and O_3 with differential optical absorption spectroscopy (DOAS), O_3 (UV-absorption monitor), NO and NO_y (chemiluminiscense monitor), H_2O_2 and aerosols (metals, SO_4^{2-}, Cl^-). In addition, measurements of vapour phase HNO_2 and HNO_3 and particulate nitrate are made in short periods.

In 1992, development of methods for measurements of VOC (volatile organic compounds) and organic peroxides is planned and continuous measurements of peroxyacetyl nitrate (PAN) and peroxypropionyl nitrate (PPN) will begin.

Photochemical air pollution is closely linked with the occurrence of nitrogen oxides. Nitrogen oxides are important precursors for the formation of photochemical air pollution (Nielsen and Lohse, 9.4), and PAN and PPN are two important photochemical oxidants. It has also been found that nitric acid and particulate nitrate are the final products of the oxidation of nitrogen oxides, contributing to acid rain and nitrogen eutrophication. The formation of sulfuric acid, nitric acid and particulate nitrate is promoted by photochemical oxidants. Therefore, the Danish TOR project focusses on the composition of nitrogen compounds.

Thus, the composition of nitrogen compounds was studied in detail during the period August 15-20. Some of the compounds were determined by more than one method, NO_2, HNO_2 and particulate NO_3^-. Satisfactory agreements were achieved. HNO_2 was not detected (< 0.03 μg N/m^3). PAN was evaluated by means of the empirical relationship established earlier.

PAN (μg N/m^3) = 0.58 * ((O_3(ppb) - 30)/15), and PPN = 0.2 * PAN.

The first part of the period was at the end of a long and dry spell with elevated concentrations of air pollutants. An occluded front from the north-west passed on August 16th, followed by a second front in the late evening of August 17th. The average concentration of total NO_y (including particulate NO_3^-) was 4.4 μg N/m^3. The composition of NO_y was: NO (0.4 μg N/m^3 - 8%), NO_2 (2.5 - 57%), HNO_3 (0.1 - 3%), NO_3^- (0.7 - 15%), PAN (0.1 - 2%), PPN (0.03 - 0.7%), and the residual amount (organic nitrates) (0.5 - 12%).

The residual amount was highest in the measuring periods 15:18^{oo}-16:06^{oo}, 16:06^{oo}-16:18^{oo}, and 20:06^{oo}-20:18^{oo} (Fig. 2.2.). Also a residual amount was observed in the measuring periods 17:06^{oo}-17:18^{oo}, 18:18^{oo}-19:06^{oo}, 19:06^{oo}-19:18^{oo} and 19:18^{oo}-20:06^{oo}, although these amounts are too small to be significant. Interestingly, the residual amount was zero or slightly negative in the measuring periods 16:18^{oo}-17:06^{oo}, 17:18^{oo}-18:06^{oo} and 18:06^{oo}-18:18^{oo}. This seems reasonable, as the air pollution was low in these periods and the air chemistry diminished, due to clean air masses following the cold fronts. These preliminary results suggest the possibility of the presence of significant amounts of organic nitrates in rural areas of Denmark.

A comparison of the results of volatile NO_y with those of NO_2 (DOAS) for August and September, confirms the presence of substantial amounts of nitrogen oxides in excess of NO and NO_2, as NO_2 is less than the difference between NO_y and NO:

NO_2 (DOAS) (ppb) = 0.53 * (NO_y - NO) (ppb) + 0.55, ($r = 0.58$; $p < 0.001$).

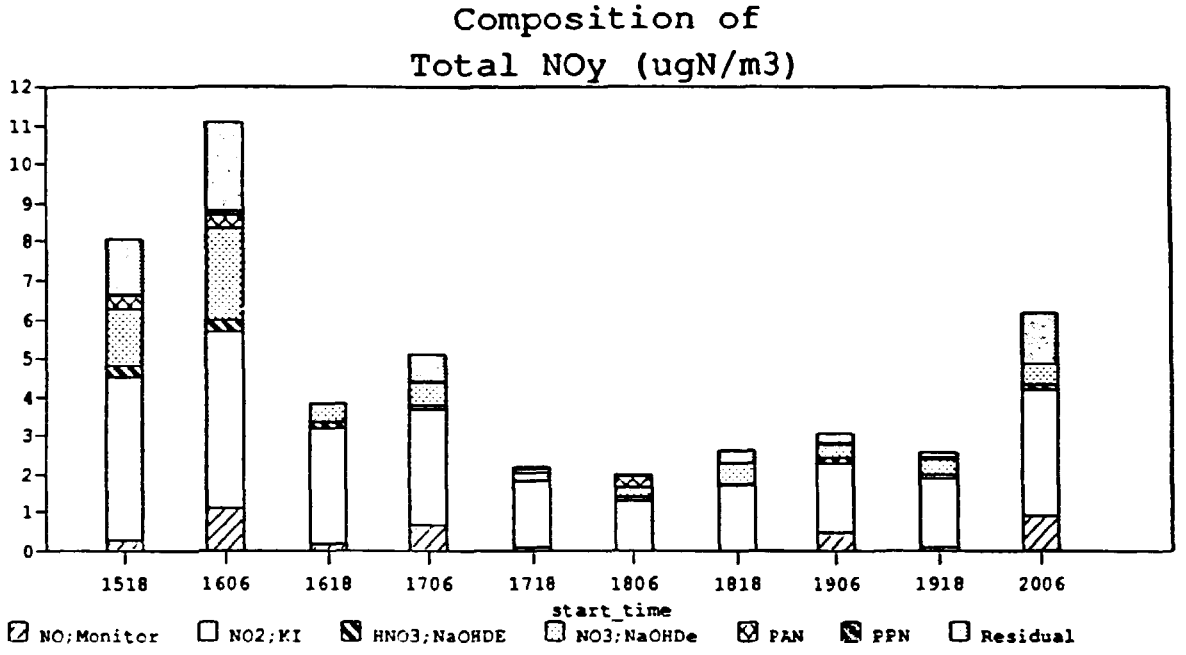

Figure 2.2. The composition of atmospheric nitrogen compounds at Lille Valby in the period 15–20 August.

Polycyclic Aromatic Hydrocarbons

Air pollution by PAH (polycyclic aromatic hydrocarbons) has been investigated for many years, one reason being that several PAH are carcinogenic. The atmospheric chemistry of PAH has been studied in detail. Analytical methods were developed, as well as methods for determining the source contributions. An article concerning this is in press.

Within DCAR, a traffic PAH project has been planned and organized to start in January 1992. The project will provide PAH data from different locations in the initial phase of the introduction of catalyst-equipped cars. Another aim of the project, is to determine the contributions from gasoline- and diesel-driven cars, respectively.

3 Plant Genetics and Resistance Biology

Methods for identification, characterization and quantification of genetic variability are essential to many basic and applied research programmes in agricultural and environmental sciences. Exploitation of genetic variability, related to traits of economical and environmental importance in crop improvement, can be greatly facilitated by the use of marker-assisted selection. The understanding of interactions between species of plants, as well as between plants and pathogens, can be greatly facilitated by identification of changes in genetic variability under different environmental conditions. For these purposes, a large part of our research is devoted to the establishment of genetic markers, construction of genetic/physical linkage maps, and analysis of genetic diversity in populations. With these tools, the mechanisms of plant-pathogen interactions are studied with the aim of describing those gene products which are important for resistance or virulence. Further, the evolutionary processes imposed by interactions between crop plants and wild plant species or pathogens are studied.

3.1 Application of Genetic Markers

A genetic marker is a trait 1) that is relatively easy to score, 2) by which individuals can be grouped into a small number of classes and 3) for which the inheritance is well-established. The trait may be visible as for morphological markers, or may need biochemical assays as in the case of isoenzyme and DNA markers and chromosome bands. New molecular methods for the detection of polymorphisms and their exploitation, represents one of the most significant recent developments in plant biology. The RFLP (Restriction Fragment Length Polymorphism) technique, already in use for some years, is very laborious and requires the handling of genetically modified organisms and radioactive nucleotides. With the development of polymerase chain technology (PCR),new and safer mapping techniques have become available. Notably the random amplified polymorphic DNA (RAPD) technique has given promising results.

In particular, these new methods may help in understanding the genetic basis of many agronomical traits which are of a quantitative nature and governed by the interaction of many Quantitative Trait Loci (QTLs) impossible to assay independently.

RFLP Map of the Barley Genome

An RFLP linkage map of the barley genome was constructed using chromosome doubled haploid lines from a cross between the winter barley variety ('Vogelsanger Gold') and the spring variety ('Alf'). This was assisted by international cooperation and the exchange of markers. The map and markers provided the basis for a cooperative project with the Danish barley breeders.

The Laevigatum resistance gene against barley powdery mildew, has been used in barley breeding for many years (H.P. Jensen *et al.*, 9.2) and is now localized to chromosome 2. This previously unlocalized resistance locus has been given the name MlLa. The locus was found to belong to a linkage group spanning 119 cM. This group consists of the v (2 rowed/6 rowed) marker and 10 RFLP markers bordered by 2 peroxidase loci. The chromosomal location was determined by 1) hybridization of RFLP markers to the wheatbarley addition lines, 2) linkage to previously localized RFLP markers from other laboratories, and 3) linkage to the 2 rowed/6 rowed character. One RFLP marker was found to link with 1.5% recombination to the MlLA gene providing a very efficient marker for this gene. Based on previous reports, it is also highly likely that genes conditioning barley leaf stripe resistance, and resistance to the cereal cyst nematode, reside in this region of chromosome 2 (fig 3.1.1).

The development of an RFLP-based linkage map of the barley genome opens up the possibility of carrying out marker-assisted selection.

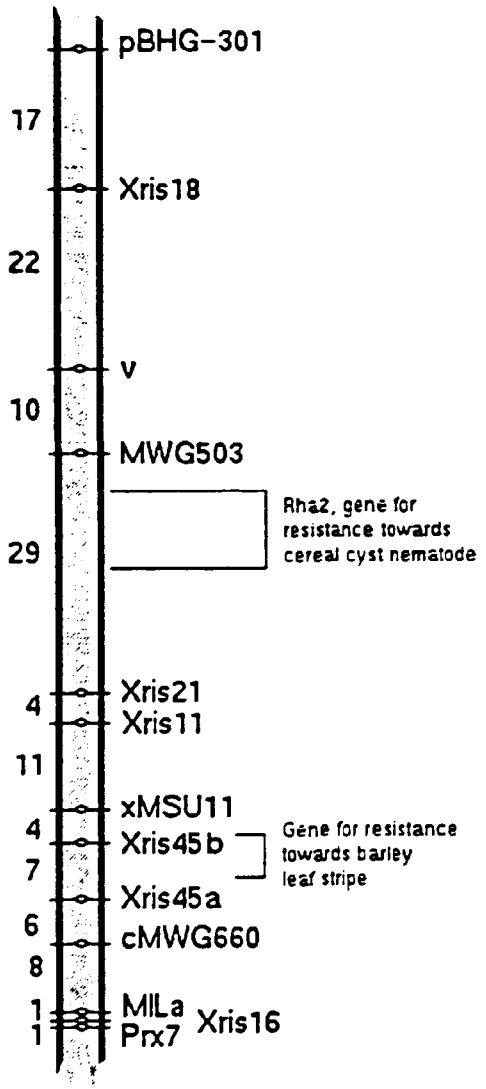

Fig. 3.1.1. Linkage map of barley chromosome 2 based on RFLP markers. The map includes the previously non-localized powdery mildew resistance locus Mla. The likely positions of resistance genes towards cereal cyst nematode race 2 (Rha2) and for resistance towards barley leaf stripe are indicated.

In plant breeding, introduction of resistance genes from primitive landraces of barley has been inhibited by the carryover of unfavourable genetic background material. Early and efficient selection for the desirable genetic background will facilitate the use of wide crosses in barley breeding. Currently, RFLP analysis of the first backcross generation individuals, derived from a cross between a primitive Ethiopian line, containing a potentially new resistance gene to barley powdery mildew, and a modern variety is being undertaken (Petersen, 9.2). On the basis of this analysis, the variation in the content of recurrent parent genes in the population will be estimated.

RFLP markers were employed in determining the genetic variability in a number of barley varieties, such as landraces from Ethiopia and Nepal, and *Hordeum spontaneum*. Preliminary results indicate that the landraces and *H.spontaneum* display greater variability in this respect than the cultivated lines and this is in accordance with most results from other marker studies.

Map of the Barley Powdery Mildew Genome

The barley powdery mildew fungal genome has been analyzed using RFLP markers. A linkage map consisting of 50 RFLP loci and 5 virulence loci has been constructed. However, most of the RFLP markers were represented at more than one chromosomal site. Thus localization of single copy sequences failed with this method. In order to obtain markers suitable as startpoints for chromosome walking towards specific virulence loci, other markers were required. The RAPD marker system has been successfully adapted to the fungal system, and DNA extraction methods, to obtain pure DNA from small amounts of fungal spores, have been developed. The RAPD markers found were reproducible and segregated according to Mendelian expectation in off spring lines. On the basis of these results, a M.Sc. thesis has been written (Justesen, 9.4). Collaboration on the mapping of RAPD markers was initiated with a group in Zürich.

The genome has also been characterized cytologically, as well as by pulse field gel electrophoresis. Seven or 8 chromosomes were identified cytologically (Fig. 3.1.2), but only 5 bands could be resolved by electrophoresis (Borbye *et al.*, 10). The bands were of high molecular weight.

Fig. 3.1.2. Light microscopy of mycelia from E. graminis f.sp. hordei with orcein-stained DNA (Bar indicates 10 µm). The cell at somatic metaphase shows the presence of seven to eight chromosomes. Two of the chromosomes are often connected. The shape of the chromosomes varies from triangular and rodlike to circular. The nucleolus is very persistent and therefore hiding the nucleolus-forming chromosome. We establish the chromosome number of the barley powdery mildew fungus to be at least n = 7.

RAPDs of Norway Spruce

With the aim of developing molecular genetic methods suitable for "high density genome mapping" in Norway spruce, this project was initiated in collaboration with the Arboretum, RVAU, in 1991. The goal is to produce a saturated genome map of about 200 gene loci. With this map, a search of linkage to quantitative trait loci, important for the breeding objectives in Norway spruce, can begin. This field of research is considered to be an important component in the long-term breeding strategy of Norway spruce, since early selection, based on markers for late expressed characters in the long living trees, will speed up the breeding programmes.

Up to now, DNA extraction of needles, buds, germinating embryos and the seed endosperm has been performed and optimized. It has been demonstrated that the RAPD technique is usable on DNA extracts from all four types of tissue mentioned. The results are reproducible but the process requires further refinements. A promising degree of polymorphism was observed.

RAPDs of Cotton

To help with the improvement of cotton breeding in India and Thailand, a project aimed at transferring biotechnological experience to these countries was initiated in 1991 in collaboration with a Danish textile merchant, and local scientists and breeders.

Preliminary experiments were carried out on material from Indian and Thai cotton plants grown in a greenhouse. A method has been established to extract DNA from cotton leaves, although this method still needs optimization. The cotton DNA was purified and successful restriction enzyme digestion was performed. The RAPD technique was used on cotton DNA and the band patterns obtained were reproducible. The next step is to search for polymorphisms using RAPDs as molecular markers.

Quantitative Trait Loci of Barley

Most of the important characters of agricultural crop plants show continuous variation and are usually assumed to be controlled by many genes. Little is known about the Quantitative

Trait Loci (QTL) which underlie continuous variation. Mendelian markers, in particular isoenzyme and RFLP markers, were used to detect associations with quantitative traits in barley (Kjær *et al.*, 9.1, J.Jensen, *et al.*, 9.2).

A field trial, with two nitrogen levels and two replicates, was carried out in 1991 with 79 chromosome-doubled haploid (DH) lines from a cross between the varieties ('Tystofte Prentice') and ('Vogelsanger Gold'). This material was recorded for a range of quantitative traits important for yield. Further, nitrogen and phosphorous uptake was recorded. Preliminary analyses of grain yield, straw yield, thousand grain weight and heading date, using 19 markers, showed that variation in all the quantitative traits correlated with the variation of the morphological marker v (2 rowed/6 rowed). An RFLP marker at one end of a group of seven Mendelian markers located on chromosome 5, was linked with a QTL for straw yield.

Chromosome-doubled haploid lines from new crosses between modern varieties are being established and the derived lines multiplied to produce sufficient quantities of seed for field trials.

Various statistical methods and computer programmes for mapping QTLs have been applied and compared.

Cytogenetics of Barley and Related Species

In situ hybridization of DNA probes to chromosomes can be used to locate the position of gene loci cytologically. A project has been initiated, using *in situ* hybridization, for elucidating the connection between distances based on recombination frequencies and physical distances on the chromosomes of barley. The procedure for making chromosome preparations and the *in situ* hybridization technique are being optimized. The technique has already been used to support an autoploid origin of the tetraploid cytotype in the wild barley *Hordeum marinum* ssp. *gussoneanum* (4x) by comparing its rDNA segments with those in *H. marinum* ssp. *gussoneanum* (2x).

In barley, chiasma formation is localized distally in the chromosomes. It would be of interest to introduce chiasma formation at other positions. This was attempted through hybridization of barley with rye, carrying accessory chromosomes (B chromosomes) that are known to influence chiasma localization. Eighty-six crossing attempts resulted in five plants. The application of Giemsa C-banding revealed that two normal green plants were haploids of barley and three necrotic plants were barley × rye hybrids with one or two B chromosomes, often in the form of isochromosomes. Three months after crossing, B chromosomes were eliminated from all tissues. Only one plant survived to produce flowering shoots (Linde-Laursen, 10b.

Cultivated barley is one of the 32 species in the barley genus (*Hordeum*). These species have been studied in various projects all in collaboration with Roland von Bothmer, Svalöv, and Niels Jacobsen, RVAU. The relationships between these species were assessed using Giemsa C-banding which produces species-specific patterns of cross-bands on the chromosomes (Fig. 3.1.3). Cultivated barley and the wild barley, *Hordeum bulbosum*, are rather closely related, whereas they are distantly related to the other barleys. (Linde-Laursen *et al.*, 10). This implies that the transfer of valuable genes, *e.g.*, genes for disease resistance, from the wild species to cultivated barley, will be difficult by traditional methods. As an illustration, sixty-five spikes of a *H. lechleri* × *H. vulgare* F_1 hybrid backcrossed with *H. vulgare* resulted in four apparently well-developed embryos in addition to a number of very small ones; however, none germinated.

Uniparental chromosome elimination, producing aneuploidy, occurs frequently in interspecific *Hordeum* hybrids (Bothmer *et al.*, 9.1). Based on chromosome identification through Giemsa C-banding patterns, elimination was studied in *H. lechleri* × *H. vulgare* hybrids. Contrary to previous study of a sample of the same parental combination, in which all 18 hypoploids had retained barley chromosome no. 6 (Linde-Laursen and Bothmer, 9.2), elimination of this chromosome occurred at a low frequency in the present sample. Meiotic metaphase I in pollen mother cells (PMCs) of a hybrid with 2n=26 which had lost barley chromosomes 1 and 6 plus one *H. lechleri* chromo-

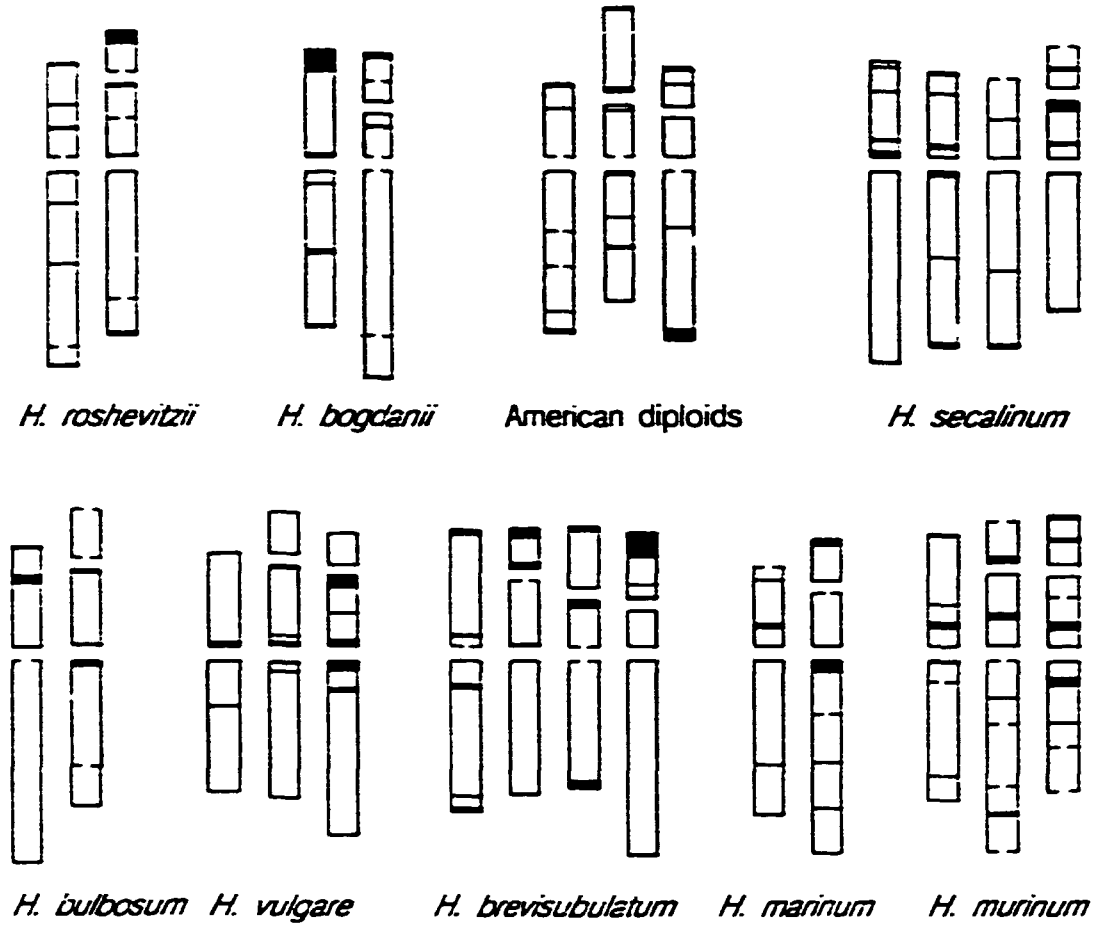

Fig. 3.1.3. Marker chromosomes of 9 Hordeum species. Similarities of Giemsa C-banded karyotypes suggest a rather close relationship between the East Asian Hordeum brevisubulatum ssp. brevisubulatum, H. roshevitzii and H. bogdanii and all Hordeum ssp. of the Americas, and distinguish the above mentioned ones from other Hordeum spp.

some, but had two copies of barley chromosome 7, produced "buds" with different numbers of chromosomes. This possibly contributed to a high frequency of PMCs with low chromosome numbers.

In situ Hybridization to Tissue Preparations

In situ hybridization technique is used to get a better understanding of the regeneration process of plants from barley microspores (pollen). It is also used to compare gene expression patterns of embryos, formed from microspores in culture, with those of zygotic embryos, formed *in placenta*.

The project is carried out in collaboration with Dianna Bowles at The University of Leeds, UK. Her laboratory has isolated and characterized a number of genes from zygotic embryos and has information on the temporal and spatial regulation of these genes during embryo development *in placenta*.

At Riso, we have well-established microspore cultures, in which cells undergo embryogenesis (Larsen *et al.*, 9.1, Nielsen, 9.4). Embryogenic structures/tissue from these microspore cultures have been selected, fixed and embedded in paraffin. The embryo specific cDNA-probes are being used in *in situ* hybridization to tissue preparations of developing

microspore-derived embryos to obtain markers for the regeneration process. This will provide information on the temporal and spatial expression of the genes. These DNA probes can then be used as markers for the regeneration process.

3.2 Mechanisms of Plant-Pathogen Interactions

Many different types of general defence mechanisms exist in plants against fungal attack. We have studied the chemical compounds callose, peroxidase, and chitinase of barley and rapeseed, and various phenolic compounds of barley. Genetic resources of species-specific resistance in barley to powdery mildew and leaf stripe have also been investigated. Finally, a strong effort was put into elucidating the very specific interaction based on gene-for-gene recognition in the barley/powdery mildew system. The study of the genetical mechanisms underlying the plant-pathogen interactions was facilitated by the ongoing characterization of the genomes of barley and barley powdery mildew.

Callose Synthesis in Barley Leaves

Barley and other plants respond to pathogens or physical damage by forming cell wall appositions, papillae, between the plasma membrane and the cell wall in the epidermal cells. The main component of the papillae is the polysaccaride callose, which is 1.3-ß-linked glucose units. Callose is synthesized by the plasma membrane bound 1.3-ß-D-glucan synthase from the substrate UDP-glucose.

Sample purification by the sucrose gradient purification technique and product-entrapment of the enzyme have pointed towards 3 polypeptide components as possible candidates of the holo-enzyme (Pedersen, 9.2). The molecular weight of the polypeptides is 35, 55, and 170 kD, respectively. Attempts to prepare polyclonal antibodies against the sub-units failed because of their low abundance. The enzyme was partially separated from most of the other plasma membrane proteins by native gel electrophoresis and ion exchange chromatography. The enzyme could be identified by fluorography and under UV-light after addition of UDP-glucose and effectors. These results are under preparation for a Ph.D. thesis.

Barley Peroxidase

Peroxidases are involved in many biological processes in plants. They are 1) tissue specific, developmentally regulated, or modulated by environmental stress factors, and 2) involved in the biosynthesis of cell walls, in the regulation of auxin level, and in response to microbial attack. Barley peroxidases are studied at the biochemical, physiological, genetical and molecular level to delineate the biological function of the individual enzymes (Rasmussen *et al.* 9.1).

It was shown that a full length cDNA for barley seed peroxidase BP 1, found by alignment with amino acid sequences of tryptic peptides of BP 1, had a 21 amino acid C-terminal extension removed. This indicated that BP 1 is targeted to the vacuoles of immature barley endosperm cells. The BP 1 molecule has one site of glycosylation only, and the sequence of the major glycan has been established showing a typical structure for plant species. Part of these results was established during two M.Sc. programmes (Johansson, 9.4, Norgaard Rasmussen, 9.4).

Cloning of genes, which code for the barley peroxidases, aims at a characterization of sequences which specify the tissue-specific expression or which are sensitive to stress factors. Well-characterized genes will be used to construct vectors for genetic transformation of barley. A genomic clone Prx6.1 coding for BP 2A, an isozyme of BP 2 purified from resting barley grains, contains an intron close to the distal histidine. BP 2A is 73% identical to BP 1, and BP 2A also contains a C-terminal extension, indicating that BP 2A might be targeted to the vacuoles. In collaboration with Novo Nordisk Ltd., recombinant strains of yeast are constructed to study the production of recombinant heme containing BP 2A proteins.

A cDNA for a peroxidase, which is induced by infecting barley leaves with powdery mildew, was used to isolate seven genomic clones.

Fig. 3.2.1. Sequence of peroxidase genes: BP 2A barley seed peroxidase; POX 1. wheat peroxidase; TAP 1. tomato peroxidase; HRP C1. horseradish peroxidase; and ATH Ca. Arabidopsis thaliana peroxidase. All peroxidase genes sequenced so far, have from one (BP 2A) to three (HRP C1 and ATH Ca) introns. The positions of introns in related genes are strictly conserved, whereas the length, as well as the DNA sequence of the introns, show no similarity at all.

The promotor will be analysed for response elements of the inducable peroxidase gene.

The single copy genes for barley seed peroxidases BP 1 and BP 2A and the powdery mildew-induced peroxidase have been RFLP-mapped to barley chromosomes. The two tightly linked loci, Prx5 and Prx6 for the seed peroxidases are linked to Est4 on chromosome 3. The leaf peroxidase loci Prx7 is mapped on chromosome 2.

From the cDNA library, in which the clone BP 1 was found, other clones for the CM α-amylase inhibitors, histone, β-tubulin and ribosome genes were sequenced. They are currently included in the RFLP mapping of the barley chromosomes.

Rapeseed chitinases

In recent years, chitinases have received attention as possible agents in plant defence mechanisms. Chitin is not found in higher plants, but is a major component in the cell walls of many fungi. *In vitro* studies have shown that chitinase is able to inhibit fungal growth by degrading chitin in the fungal cell walls.

A pathogen-induced chitinase was isolated from cotyledons of rapeseed 8 days after inoculation with *Phoma lingam*. The enzyme has a molecular weight of 30 kD. A partial amino-acid sequence was determined after tryptic digestion and was shown to have homology to amino acid sequencies from chitinases isolated from other plant species.

Inoculation of resistant and susceptible cultivars showed a significant increase in chitinase activity during the early stages of infection. Chitinase activity was restricted to the site of fungal attack and was not systemically induced.

A full length cDNA clone corresponding to the purified chitinase enzyme, was found and characterized by sequencing. The clone encodes a 268 amino acid polypeptide. Expression studies showed different induction of this enzyme in resistant and susceptible rapeseed cultivars. The structure of this gene is different from previously characterized chitinase genes and indicates the existence of a novel group of chitinases. These results are being prepared for a Ph.D. thesis.

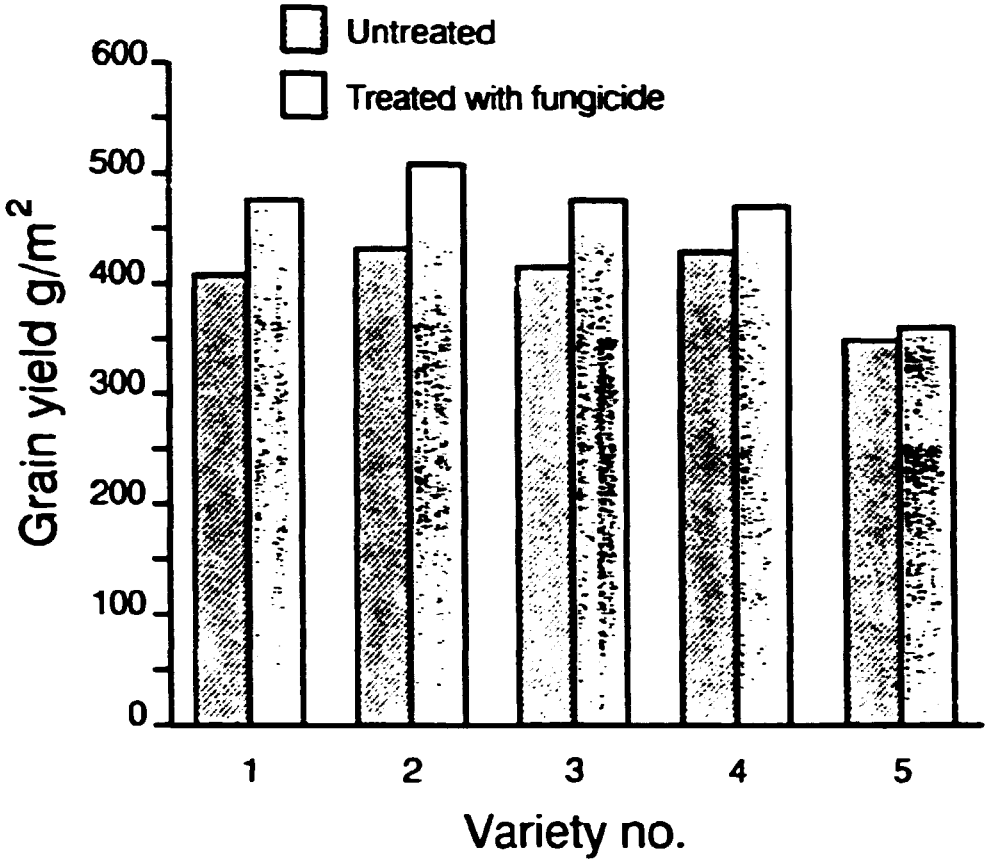

Fig. 3.2.2. Effect of fungicide treatment of barley varieties with increasing degrees of partial resistance to powdery mildew.

Phenolic Compounds in Barley Leaves

Indications that phenolic compounds are of importance in relation to resistance responses are found in some plant species. A preliminary study in barley using varieties with different degree of partial resistance was initiated in collaboration with Bodil Sogaard, RVAU.

Varieties representing the known variation in partial resistance to barley powdery mildew were grown with and without fungicide treatment, at low and medium nitrogen-fertilizer levels. The reduction in grain yield when no fungicide was applied - an estimate of the degree of partial resistance - varied from 5 to 20% irrespective of fertilizer level (Fig. 3.2.2). The mildew attack was, however moderate, so the fungicide treatment also reduced the impact of other fungal diseases.

Leaf samples, harvested during the growing period, were collected to study 1) the effect of fungicide treatment and nitrogen level on the content of different phenolic compounds and 2) the possible correlation between these compounds and the degree of partial resistance in the varieties. These assays are being carried out using HPLC techniques.

Genetic Resources of Barley with Resistance to Powdery Mildew

Over the past few years the Mlo resistance of barley to powdery mildew, characterized by a rapid and efficient papillae formation (Jorgen-

sen, 9.4b), has become distributed on about 30 per cent of the spring barley area in most of Europe. Current deliberations consider strategies for maintaining the efficiency of the Mlo resistance and to avoid a build-up of Mlo aggressiveness in natural powdery mildew populations (Andersen, 9.2, Jorgensen, 9.4, 10). The Mlo resistance in current cultivars originates from an induced mutant gene *mlo9* and some Ethiopian landrace barleys, all of which probably possess gene *mlo11*. About 3.200 landrace barleys from Ethiopia were tested for resistance. Of these, 24 had Mlo resistance. Most of them could be traced to a few locations in southwest Ethiopia (Jorgensen 10).

Ten recently discovered Mlo resistant varieties were studied for disease attack and yield in field experiments. The Mlo varieties were highly resistant to powdery mildew, but considerable variation was found in their resistance to barley leaf rust and scald. Yield losses in untreated, compared to fungicide treated, Mlo resistant varieties were correlated with the degree of leaf rust resistance.

Several new promising sources of mildew resistance have been selected. They are being utilized for barley breeding in collaboration with Danish barley breeders. Part of the material was collected at different sites in Syria and Jordan by the International Center for Agricultural Research in the Dry Areas (ICARDA) and evaluated further at Riso. In collaboration with the Nordic Gene Bank (NGB) and institutions in Norway, Sweden and Finland, Riso has evaluated NGB barley accessions for morphologic and agronomic traits, as well as for powdery mildew resistance. This activity is part of a European programme on barley genetic resources (Jorgensen 10).

Barley Leaf Stripe

The investigations, on resistance to barley leaf stripe, have been continued with the aim of obtaining highly resistant varieties for practical use. A dozen varieties, with the formerly described highly effective "Vada-resistance", have covered a considerable part of the barley

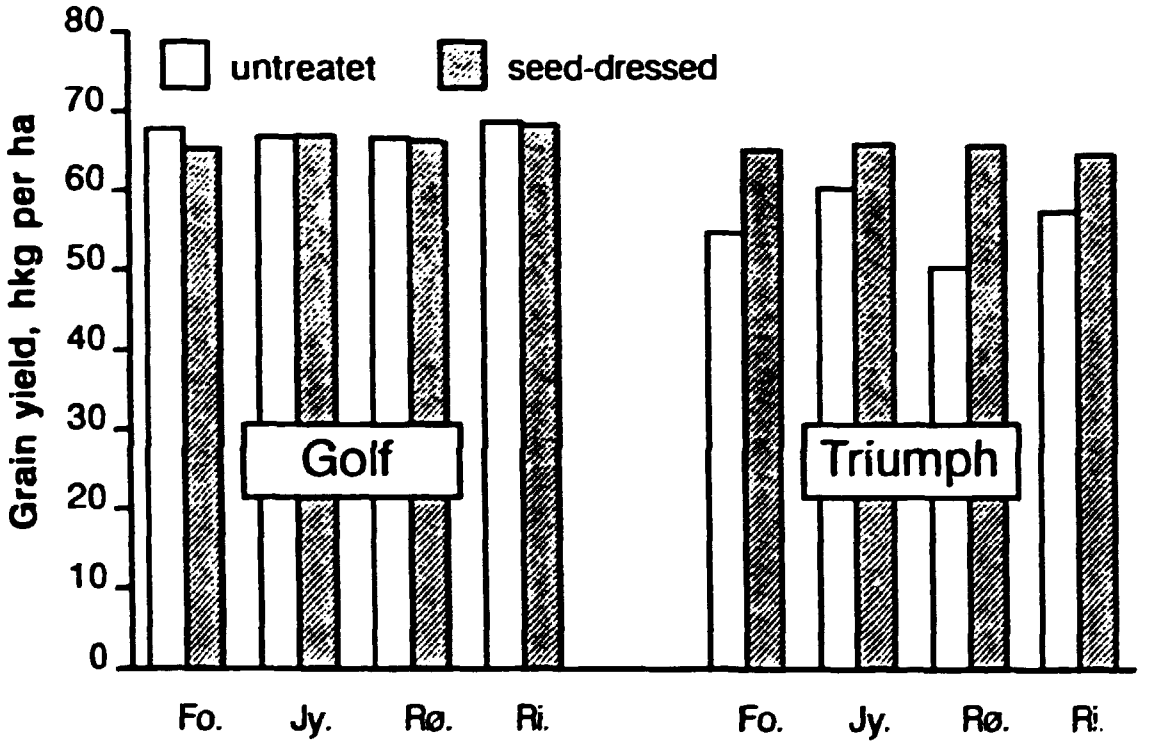

Fig. 3.2.3. The effect of seed-treatment against barley leaf stripe (Drechslera graminea) on a resistant 'Golf' and a susceptible 'Triumph' variety.

area in Denmark during the later years. It is unknown whether virulence is present in Denmark. This is under investigation, but virulence corresponding to the Vada-resistance has not yet been found among the collected isolates of the fungus.

The effectivity of the Vada-resistance has been tested during the last three years at three State Experimental Stations and at Riso in collaboration with Bent J. Nielsen, The Danish Plant Protection Institute. Uniformly, inoculated samples of the Vada-resistant 'Golf' and the susceptible 'Triumph' varieties were compared, untreated and seed-dressed with Fungazil. No disease was found in the untreated 'Golf', whereas the seed dressing caused an insignificant yield loss. On an average, there was 12.5% leaf stripe in the untreated 'Triumph' which caused a yield loss of 9.2 hkg/ha or 12.0% (Fig. 3.2.3).

It has been verified (Skou, 9.4b) that experiments with seed dressing against common seedling diseases in barley during the last 25 years never resulted in an increased yield. Thus seed dressing of the Vada-resistant varieties is unnecessary, as long as this resistance is effective.

Virulence Gene Products of Barley Powdery Mildew

The ability of individual isolates of the powdery mildew fungus to penetrate and establish themselves in the epidermal layer of barley leaves is determined by specific genes. A prerequisite is, that corresponding virulence genes in the fungus and resistance genes in the plant, match to a compatible interaction. The function of these genes is unknown and they can only be determined by the phenotype of the interaction. Two approaches, based on molecular techniques, are being used to identify the products of the virulence (avirulence) genes.

A cosmid library containing the entire fungal genome has been screened with radioactively-labeled mRNA from infected barley leaves. Sequences recognized by mRNA isolated from infected barley leaves were found, but were subsequently shown, by sequencing, to contain long polyA stretches. The method was found to be inadequate for selecting sequences expressed in the early interaction between the fungus and the plant. During the study, a highly repetitive sequence was identified and sequenced. Within one clone, two almost identical inverted copies of this sequence were found. The sequence was found dispersed throughout the powdery mildew fungal genome. A similar organization of repetitive sequences has been found in other organisms. The reason for the accumulation of large amounts of inert DNA remains unresolved.

Another approach to the isolation of virulence or avirulence genes is by chromosome walking. DNA suitable for cloning in YAC vectors was isolated. Transformation of yeast cells with the YAC vector was established and some clones containing fungal DNA were also obtained. It is, however, still a problem to obtain a sufficient amount of high molecular weight DNA in order to get a large number of transformants.

Biocontrol of Barley Powdery Mildew

Biocontrol of powdery mildew with *Tilletiopsis* species is a promising possibility in greenhouses, above 70%. Some *Tilletiopsis* species produce considerable amounts of β-1,3-glucanase, which might be a contributing factor to their effectiveness. The kinds of β-1,3-glucanases in question are under investigation in collaboration with Karsten M. Kragh and Hans Henrik Dalsgård, Danisco A/S, Copenhagen.

3.3 Population Biology

Experimental and theoretical studies of interactions between populations are important in understanding biological systems. Our research is particularly devoted to interactions between crop plants and weeds, and between crop plants and their pathogens. Exchange of genes between related species, competitive abilites of crop plants and evolution of pathogen populations are the main items investigated.

Interaction between GMPs and the Environment

Genetically modified plants (GMPs) will be marketed within a few years. The risks of gene flow from these cultivated transgenics into wild relatives need evaluation. Also, knowledge about the effect of the new genes transferred to plants in nature is needed, to evaluate the risks to the environment from transgenic varieties. In Denmark, spread of transgenes from oilseed rape to the closely related weed *Brassica campestris* ssp. *campestris* might be undesirable. *Brassica juncea*, occasionally found as a ruderal, may also be able to hybridize with oilseed rape.

Fig. 3.3.1. Hybrids between Brassica campestris (see figure) and oilseed rape are investigated by controlled crosses and under field conditions.

In a project initiated in late 1991, in collaboration with Maribo Seed, the degree of hybridization between oilseed rape and the two natural/naturalized *Brassica* species in the field will be examined. Genetic markers will be used to study the parts of the oilseed rape genome which are transferred to *Brassica campestris* ssp. *campestris* and *Brassica juncea*. *Brassica campestris* ssp *campestris* and *Brassica juncea* were collected and the first series of manipulated crosses were performed (Fig. 3.3.1).

Interaction between Crop Plants and Weeds

An understanding of the interactions between crop plants and weed plants is necessary to evaluate the extent to which crop plants can be grown without using herbicides. Cultivation without herbicides may have economical advantages, if weeds make use of growth factors which the crop is unable to utilize. In this way the bio-diversity among plants and other organisms in the agricultural fields could be increased.

The competitive ability of barley, pea, and weeds was studied in monocultures and in a 1:1 mixture of barley and pea grown with and without herbicide treatment. It was found that barley had a high competitive ability compared to those of pea and weeds. Pea was a weak competitor, and pea biomass production in herbicide-treated plots was higher than the sum of pea and weed biomass in untreated plots. Total production of pea and barley in mixtures, was about the same as those found in monocultures. Hence, combined cultivation of these two crop plants did not result in an improved utilization of the growth factors. This project was carried out in collaboration with Bodil Sogaard, RVAU.

Modelling the Dynamics of Powdery Mildew Populations

One way to decrease the use of pesticides in crop management is to use genetically determined resistance in barley to the powdery mildew fungus.

The implication of different strategies for exploiting this genetic resistance has not yet been worked out in detail.

A project aimed at studying this problem was started in late 1991 at Risø in collaboration with Mogens Hovmøller (Danish Institute of Plant and Soil Science) and Lisa Munk (RVAU). This work will be based on newly established models of changes in virulence gene frequencies of aerial powdery mildew populations, as a result of selection induced by resistance genes in barley (Hovmøller and Østergård, 9.2).

Taxonomy of *Chrysosporium* Species

Xerophilic *Chrysosporium* species are often found in association with the fungi of *Ascosphaeraceae*, which cause diseases in solitary bees used for pollination. Ten new strains of these *Chrysosporium* species from Denmark, Spain, Sweden and Japan were described and taxonomocally separated, along with *C. farinicola* (Burnside) Skou (anamorph of *Bettsia alvei* (Betts) Skou) into a *Farinicola* series (Skou 10b).

4 Plant Nutrition

The objective of this research area is to provide a better understanding of those biological and chemical processes in the soil-plant-atmosphere environment, which are important for the provision of plant nutrients. The processes must be utilized and managed in such a way that nutrient uptake by plants is optimized. This will lead to a reduced requirement for energy-consuming fertilizers and to a smaller loss of nutrients to the aquatic and atmospheric environments.

Mutualistic associations between plant roots and microorganisms are directly involved in the nutrient uptake by plants. Nitrogen is provided by *Rhizobium* bacteria, fixing atmospheric nitrogen in symbiosis with legumes. The soil-plant transport of mineral nutrients, especially phosphorus, is mediated by VA mycorrhizal fungi in symbiosis with most plant species.

The general soil microflora is a biological resource of fundamental importance to the mineralization of nutrients contained in plant residues and in farmyard manure. Special attention is directed towards processes involved in the cycling of nitrogen, which constitutes not only a major nutrient source for plants, but also a risk to the environment by leaching and gaseous losses.

The study of these research topics will provide the basic information needed for increasing the economical and ecological sustainability of plant production.

4.1 Nitrogen in Soil and Plants

Our aim is to elucidate the intricate biological, physical and chemical processes involved in the cycling of nutrients in the soil-plant-air system. At present, the main emphasis is on processes involved in the cycling of nitrogen (N) in crop residues, catch crops, farmyard manure and mineral fertilizers.

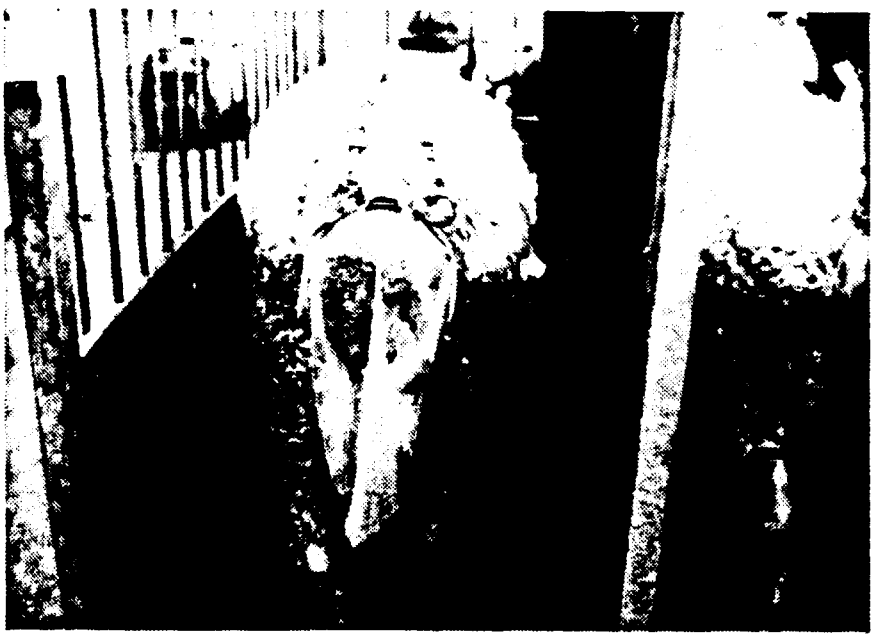

Fig. 4.1.1. The organic fraction of animal manure are labelled by feeding sheep with ^{15}N labelled ryegrass and separately collected urine and faeces.

Cycling of N from Crop Residues and Manure

Nitrogen, mineralized from crop residues and farmyard manure, contributes to the nitrogen nutrition of succeeding crops, but may also be lost by leaching and denitrification. Plant materials and manure labelled with ^{15}N, are used for studying the mineralization and plant uptake of N from organic N sources.

The plant accumulation of N in autumn-sown winter oilseed rape and winter barley from ^{15}N labelled pea straw was studied in a field experiment during 1990-91. Pea straw with 2.6% N, corresponding to 83 kg N/ha was incorporated in the top soil in September 1990. At growth analysis in early December 1990, the total N accumulation in roots and shoots of both crops was about 10 kg N/ha higher after incorporation of pea straw as compared to no straw incorporation. The higher uptake equalled the actual uptake of ^{15}N from the pea straw, showing a recovery of 13% of the added straw N in December. The crops were fertilized with 100 kg N/ha in the spring of 1991, and the increase in total N from December 1990 until harvested in late July 1991 was 160-190 kg N/ha. Incorporation of pea straw in the autumn also had an effect on final N accumulation in the crops. Despite the high uptake of N during the growth season, the recovery of labelled N from the pea straw in barley and oilseed rape was only 16% and 14%, respectively. These results indicate that the main part of pea straw N mineralization takes place during the autumn. Consequently, it is important to establish a crop in the autumn after the cultivation of pea, in order to utilize the N mineralized from the pea crop residues as efficiently as possible.

Studies on the mineralization of N from the organic fraction of farmyard manure have been initiated. A method for labelling the manure with ^{15}N is being evaluated. The preliminary results show that the ^{15}N enrichments of the different organic N fractions of the manure were not completely homogeneous. The easy decomposable nitrogen fraction was slightly less labelled than the total manure N.

The plant uptake of nitrogen from ^{15}N-labelled sheep manure was studied in micro-plots in the field. The labelled faeces contained 3.2% N (in DM) and negligible amounts of mineral N. In April, 84 kg N/ha in manure and 90 kg N/ha of unlabelled NH_4-N were applied to the soil to simulate a cow slurry addition.

The N uptake in spring barley was studied in 3 soils with 17%, 8.5% and 4% clay, respectively. About 13% of the labelled N was recovered in the above ground parts of the barley plant, irrespective of the clay content of the soil. Calculated by the difference in the N uptake between barley, with and without addition of manure, the apparent uptake in barley from manure N was 6.6%, 9.5% and 15.3% in the 3 soils. These results indicate a higher immobilization and/or denitrification rate of mineral N after manure application in the soils with the higher clay content. Consequently, the fertilizer value of manure N to spring barley was higher in sandy soils compared to that in clayey soils, even though the mineralization of organic manure N was nearly the same in the different soil types.

Nitrogen Accumulation in Winter and Spring Types of Agricultural Crops

The cultivation of autumn-sown crops has increased considerably during recent years. This is partly due to environmental concern about the leaching of nitrate from agricultural areas and the claim by "Program for protection of the water environment" that 65% of the arable land must be covered by growing crops for as long as possible during autumn and winter. A crop rotation experiment was initiated in 1985 to measure the nitrogen utilization by winter and spring types of barley, rape, wheat and rye grown in this sequence in field plots receiving increasing amount nitrogen fertilizers.

The results have shown that the nitrogen accumulation by the winter types during the autumn, varied considerably between years, depending on planting time and growth conditions (Andersen *et al.*, 9.3). Sowing later than normal, in the autumn, resulted in a nitrogen accumulation in December, which was less than half the potential in crops sown at the right time and grown under favorable growth conditions. Comparison of total nitrogen accumulation in winter and spring types at maturity,

showed that differences between the two types of crops were highly dependant on the amount of nitrogen fertilizer supplied. At the lowest N levels almost no differences were found, whereas at higher N levels the winter types accumulated 30–50 kg N more per ha than the spring types. Considerable variation, however, occurred between years.

The results emphasize, that comparison of nitrogen utilization by winter and spring types, should be based on crop rotation experiments performed over several years and with due consideration to differential rate of growth.

4.2 Root-Microbe Symbioses

Symbiotic associations between plants and soil-microorganisms are of major importance to plant nutrition. Our research in this field includes the physiology and ecology of the legume-*Rhizobium* symbiosis and VA mycorrhiza, a symbiosis between plants and fungi.

Symbiotic N Fixation

The ability of legumes to establish a symbiotic relationship with *Rhizobium* bacteria which fix atmospheric nitrogen into ammonia, has been essential in sustaining the fertility of agricultural land for centuries. Symbiotic N fixation is fuelled by products from the photosynthetic activity of the plant. This input of nitrogen into the crops is derived from solar energy, rather than from the fossil energy used to produce nitrogen fertilizer.

The *Rhizobium* bacteria inhabit root nodules on the legume, where they transform to the nitrogen-fixing bacteroid stage. In effective root nodules, the *Rhizobium* bacteroids are enclosed by a plant-derived peribacteroid membrane (PBM).

Information on the exchange of compounds between the host plant and the microsymbiont across the membrane interface is valuable, because it reflects how a mutualistic relationship is maintained. Furthermore, the rate of symbiotic nitrogen-fixation is likely to be controlled by this exchange of compounds (Rosendahl *et al.*, 9.1).

We have isolated metabolically active bacteroids enclosed by an intact PBM from pea root nodules. These structures (peribacteroid units, PBU) were incubated in reaction mixtures containing various ^{14}C-labelled compounds. By detecting the fate of the ^{14}C within the PBUs and in the reaction medium, we have demonstrated an exchange of organic acids for amino acids between the symbionts (Rosendahl *et al.*, 10). The results indicate that the enzymes involved may be located in the membrane interface, either associated with the membranes, or found in the space between the PBM and the bacteroid outer membrane. We have verified that the space between the symbionts contains a discrete set of proteins. Involvement of some of these proteins in the exchange of metabolites is currently being investigated.

Mycorrhizas and Plant Nutrition

The formation of vesicular-arbuscular mycorrhiza (VAM) between plant roots and soil fungi has a beneficial impact on the nutrient uptake by the plants. Nutrients in the soil solution are absorbed and transported to the roots by the external fungal hyphae. A two-compartment system makes it possible to distinguish hyphal nutrient uptake from direct uptake by the roots. A hyphal compartment is separated from the root compartment by a fine mesh, which restricts root growth, but allows free passage of the hyphae.

Hermetically sealed two-compartment units were used for measuring the carbon:phosphorus (C:P) exchange ratio of three VAM fungi in symbiosis with cucumber plants. An aqueous solution of ^{32}P was supplied to the hyphal compartment of 3-week-old plants just before the exposure of shoots to a $^{14}CO_2$-enriched atmosphere for 16 h. The ^{14}C transported to the hyphae, and the ^{32}P transported to the plants, were measured after a 72 h chase period. The C:P exchange ratio differed markedly between the fungi. This was caused mainly by major differences in fungal P transport, rather than in the fungal C drain, which did not differ in the three isolates. The length of external hyphae also differed markedly between fungi, but P transport was not related to amounts of hyphae.

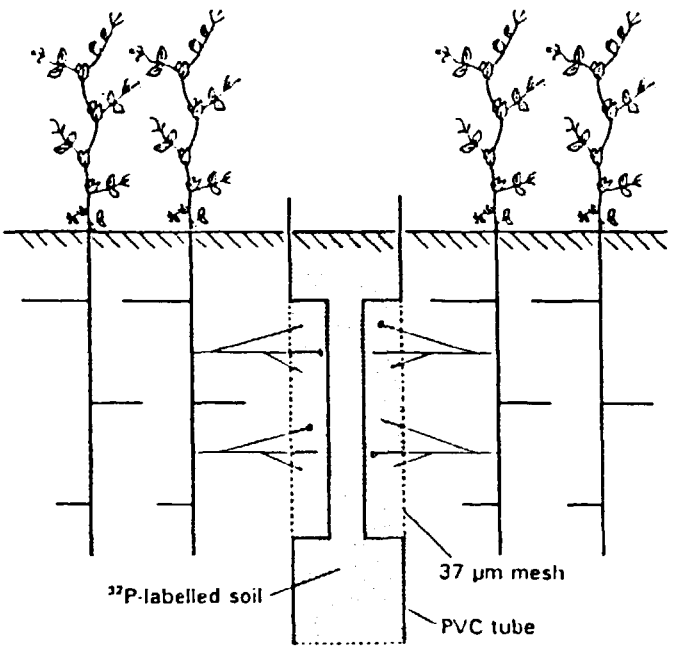

Fig. 4.2.1. Two compartment system for studying hyphal P transport to pea in the field.

The two-compartment system has been used to directly demonstrate P transport by VAM hyphae under field conditions. PVC tubes, with most of their walls replaced by a fine mesh, served as hyphal compartments. They were buried in the plough layer of plots with pea plants (Fig. 4.2.1.) and the tubes were filled with ^{32}P-labelled soil. The specific radioactivity (cpm/g leaf P) was considerably higher in mycorrhizal pea plants than in nonmycorrhizal plants grown in fumigated plots (Jakobsen *et al.*, 10).

Hyphae of VAM fungi are also able to transport nitrogen (N) to their host. Soil in a hyphal compartment was supplied with ^{15}N-labelled ammonium and the hyphal transport of ^{15}N by a single VAM fungus was studied in relation to the N status of cucumber plants. Mycorrhizal plants with low and medium N status (105 and 217 mg N) contained 45% of the applied ^{15}N after 27 d; the corresponding figure for plants with high N status (425 mg N) was only 26%. This indicates that the symbiosis may control the hyphal N transport in relation to the N demand of the host.

The rate of hyphal transport of P and N was studied in subterranean clover associated with a single VAM fungus. ^{32}P and ^{15}N were supplied to a hyphal compartment at 2 and 5 cm distances from the root compartment. Transport into the plant was measured by the presence of the isotopes in leaflets harvested each day from young fully expanded leaves. After only three days, the radioactivity was higher in the leaves of mycorrhizal plants than in those of nonmycorrhizal plants. After this lag phase, the radioactivity in mycorrhizal plants increased sharply. ^{15}N analysis are not yet finished, but the results seem to be confounded by the transport of ^{15}N in the soil by mass flow.

The influence of soil organic matter on production of VAM hyphae was studied with mycorrhizal cucumber. Moist soil amended with chopped wheat straw (0, 10, 30 or 90 g/kg soil), was incubated for 14 months. The mixtures were filled into hyphal compartments and the mycorrhizal plants were grown for 31 d. The length of external hyphae was increased when increasing amounts of straw were supplied. The background for this interaction is not yet known, but the influence of organic matter seemed to be exerted directly on the external hyphae, since root colonization was not affected.

Nitrogen Transfer from Legumes to Non-Legumes

Nitrogen fixed symbiotically contributes mainly to the N nutrition of the legume host, but N mineralized from legume root exudates, nodules and roots may contribute to the N nutrition of other plants growing in association with the legume. Furthermore, if plants are colonized by a common VA mycelium, nutrients may be transferred from legumes to non-legumes. Interspecies transfer of nutrient is being studied using ^{15}N and ^{32}P as tracers.

In experiments carried out under controlled environmental conditions with intercropped pea and barley, pea plants were labelled with ^{15}N using either a split root labelling procedure or leaf labelling with ^{15}N. Both labelling methods demonstrated that the transfer of ^{15}N from pea to barley occurred before the pod-filling growth state. Using split root labelling for 35

days, the results showed that a total of 2% of the N in pea was transferred to barley, when pea and barley roots occupied the same soil volume. The N transferred, corresponded to about 15% of total N in barley, when plants were grown with a low supply of mineral N. When the plant root systems were separated by a 20 μ nylon mesh, the transfer of pea N was about 50% of the transfer in the treatment with roots growing in the same compartment.

Risø and The Rubber Research Institute of Malaysia are currently studying the pathways of N transfer from a creeping cover crop legume (*Pueraria phaseoloides*) to rubber trees (*Hevea braziliensis*). The main focus is on the role of VA mycorrhizas in the transfer of N and P.

Fig. 4.2.2. Rubber trees (Hevea brasiliensis) are grown with a cover crop legume (Pueraria phaseoloides) in compartmented containers for studies of N and P transfer. Rubber left side of boxes.

4.3 Effects of Air Pollution on Plants

Forest Decline and Ammonia

A serious decline in Norway spruce (*Picea abies*) has caused much damage to plantations in Jutland during the last 3–4 years. Up to 20% of the trees have died, particularly along forest edges. Among the many hypotheses on the causes are mild winters, making trees respire themselves to death, salt damage after gales, overfertilization with ammonia from the air, or a combination of these stresses. Most of western Jutland is a pristine area with low air pollution, but calculations indicate that up to 50 kg ammonia may be deposited per ha, liberated from fertilization with slurry and from stables.

We are investigating the reaction of 4- and 2-year-old Norway spruce in pot cultures in sand, to overfertilization with nitrogen relative to P, K and the other nutrients. Heavy fertilization with nitrogen over 2 years resulted in needle loss in the older seedlings, and some symptoms were evident after 1 year in the small seedlings. However, the symptoms are not exactly like those seen in the field, in Danish called "rode rodgraner".

Does Ozone Interfere with Carbon Translocation in Wheat?

The effect of ozone on the transport of assimilates was studied in collaboration with Department of Emissions and Air Pollution, NERI (National Environmental Research Institute) in the Open Top Chamber facility. Ozone-damaged plants often show altered carbon allocation with reduced root growth, and the present investigation was done to find out if the cause of these effects might be due to a reduction in translocation velocity or efficiency.

Spring wheat plants grown in standard air, in air filtered through activated carbon, or in air with added ozone, were allowed to take up radioactive CO_2 in a small leaf cuvette for 5 minutes. The plants were harvested after different intervals, freeze dried and autoradiographed on X-ray films. The amounts of radioactivity were measured in the plant material by scintillation counting after solubilization in sodium hypochlorite.

There were no indications that ozone interfered with the translocation process, neither in its speed nor in the percentage exported from the leaf. However, the variability in the "pseudo-field-grown" material was quite large, so that minor effects could not be discerned. It must therefore be concluded that the influence of ozone on carbon allocation can be explained by other mechanisms.

5 Chemistry of the Geosphere

5.1 Geochemical Modelling

The previously mentioned geochemical computerprogram, JENSEN, has successfully been applied to predict the possible geochemical transformations to be expected when foreign minerals are added as reactants to polluted waters. In addition, a thorough validation study of carbonate equilibria, involving both theoretical and experimental work was performed.

A new EEC contract, which was started recently, is concerned with the quantification of the behaviour of humic acid colloids exposed to multi-element salt solutions. Preliminary tests, to identify the concentration ranges of interest, have clearly demonstrated competition between ions for the available adsorption sites and thus indicate which model be applied.

In another EEC contract concerned with uncertainties in the modelling of migration, the possible effect of unknown inhomogeneities on the extent and path of migrations are studied.

The concentration distribution, resulting from three-dimensional diffusion from a source through a medium containing randomly dispersed inhomogeneities, was calculated and analysed. A linear relation between an apparent diffusion coefficient and the porosity of the medium was established, as well as the uncertainties to be ascribed to them. This relation is not valid in the case of two-dimensional diffusion.

The convective flow through networks of fissures and pores will be simulated by the adaption of Kirchhoff's laws for the flow of electricity through networks of conductors. The results of these studies will be used to describe dispersion processes and to estimate the uncertainties and other characteristics of the effective dispersion coefficients obtained. The algorithms needed for these calculations have already been constructed and tested.

5.2 Applied Geochemistry

Methods

In cooperation with the company Tracechem, application of instrumental neutron activation strategies for large-sample analysis were carried out in 1991. Theoretical and experimental data were presented at the 8th Intern. conference on "Modern Trends in Neutron Activation", Vienna, September 10 - 16, 1991. (Gwozdz *et al.*, 9.2). A book review was written for the journal Lithos (Kunzendorf, 9.1).

Radioisotope EDX measurements were applied in small projects for students of the Institute of the Environment, Technology and Social Studies, RUC. Both EDX and gamma spectrometric methods were later used by student groups involved in projects describing ferromanganese crusts and heavy mineral deposits from the isle of Anholt.

Terrestrial Geochemistry

A final report (Kunzendorf *et al.*, 9.3) has been prepared regarding the energy research project "Time-temperature variations in sediments from the Central Trough area and the Danish Subbasin evaluated by fission-track studies of cuttings from selected drill holes" (in cooperation with the University of Copenhagen).

In a recently developed 2-D basin modelling programme, fission track length distributions in apatites from drill hole D-1 (north of the Central Trough area) were measured. Using these data, instead of traditional vitrinite reflectance data, it was found that the sediments in the hole were subject to uplift/erosion before their emplacement. Furthermore, the modelling, using fission track data, also suggests subsidence of sediments at late depositional stages.

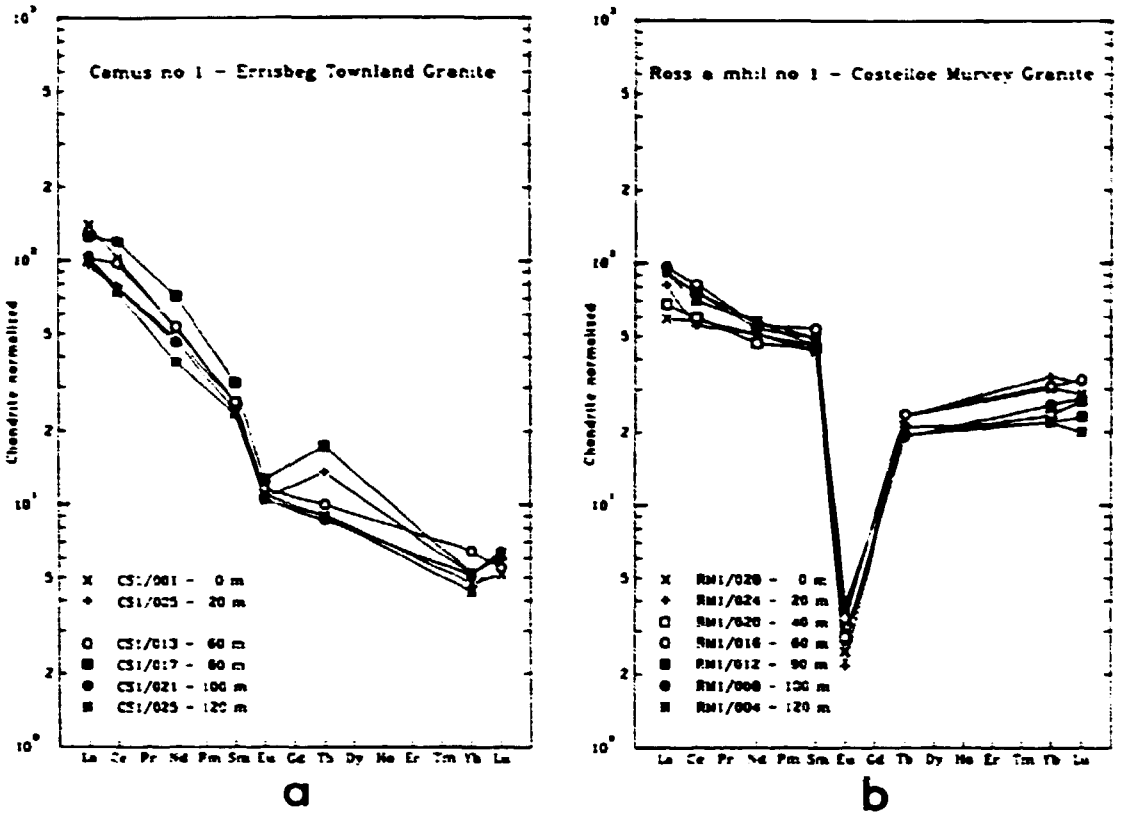

Fig. 5.2.1. Chondrite-normalised REE profiles for drill core samples of Irish granites. a = bore hole Camus no. 1, b = borehole Ros a Mhil, both from the Galway area.

Studies of rare earth elements in the Galway granites contributed to a publication by the University College Galway, Ireland (Feely *et al.*, 9.1). Based on surface and drill core samples, it could be shown that granodiorites and granites display light-REE enriched patterns, while the more evolved granites show large negative Eu anomalies and heavy-REE enrichment.

Marine Geochemistry

Rare and precious metals were studied in marine sediments and ferromanganese phases from the Pacific. Investigations of metalliferrous sediments from the back-arc spreading area, the Lau Basin (Kunzendorf *et al.*, 9.1), revealed significant amounts of gold in the sediments suggesting hydrothermal activity in the area. Results (in cooperation with the University of Heidelberg and the New Zealand Oceanographic Institute, NZOI) were published in a special volume of the journal Geologisches Jahrbuch, Hannover.

Ferromanganese crusts and nodules from New Zealand waters were analysed for rare and other elements. The data was able to devide the crusts into two different types with distinct rare earth element patterns. A summary of this work was published in the NZOI journal (Glasby *et al.*, 9.1).

Hydrogenous and hydrothermal ferromanganese crust data from the South Pacific were published in cooperation with the University of Kiel and NZOI in the journals Marine Geology and Marine Mining (Puteanus *et al.*, 9.1; Stüben *et al.*, 9.1). Our input into this work was mainly in the form of rare earth element studies.

Radiometric methods for the inspection of the sea floor are described in "Handbook of geophysical exploration at sea" to be published in 1992 by CRC Press, U.S.A. A newly developed radiometric sonde (cooperation RUC/

Riso) was tested on board the research vessel Gunnar Thorson. Data and preliminary work with the sonde were presented in the form of posters at the "2nd International Symposium on Environmental Geochemistry" in Uppsala, Sweden, and at the "Second Marine Geological Conference – The Baltic" in Rostock, Germany (Kunzendorf and Schroder a and b, 9.2).

5.3 Geochemical and Applied Technology

Marine Environmental Technology

In 1991, discussions ended regarding the scientific and technical cooperation between the Applied Geochemistry group, the Institute of Environment, Technology and Social Studies (RUC) and the Danish Road Institute (Road Directorate). Cooperation is now channelled through the Baltic Marine Cooperation (BMC) which is connected to the Center of Advanced Technology.

Fixation of Heavy Metals in Soil

The work on binding metal ions to clay minerals continues. Experiments with mercury give promising results. An experimental programme, comprising both leaching and identification of fixed species, as well as plant growth experiments, were discussed with scientists from UK and Spain in preparation for EEC support.

Preliminary pot experiments with Italian rye grass are in progress.

Wet Oxidation of Organic Material

Applied research into specific cases of pollution have continued in parallel with more fundamental research projects. The latter include an investigation of the oxidative decomposition of polyolefins and paraffins. An intriguing feature is the production of significant amounts of hydrogen during the wet oxidation.

The oxidation of dicarboxylic acids was also studied.

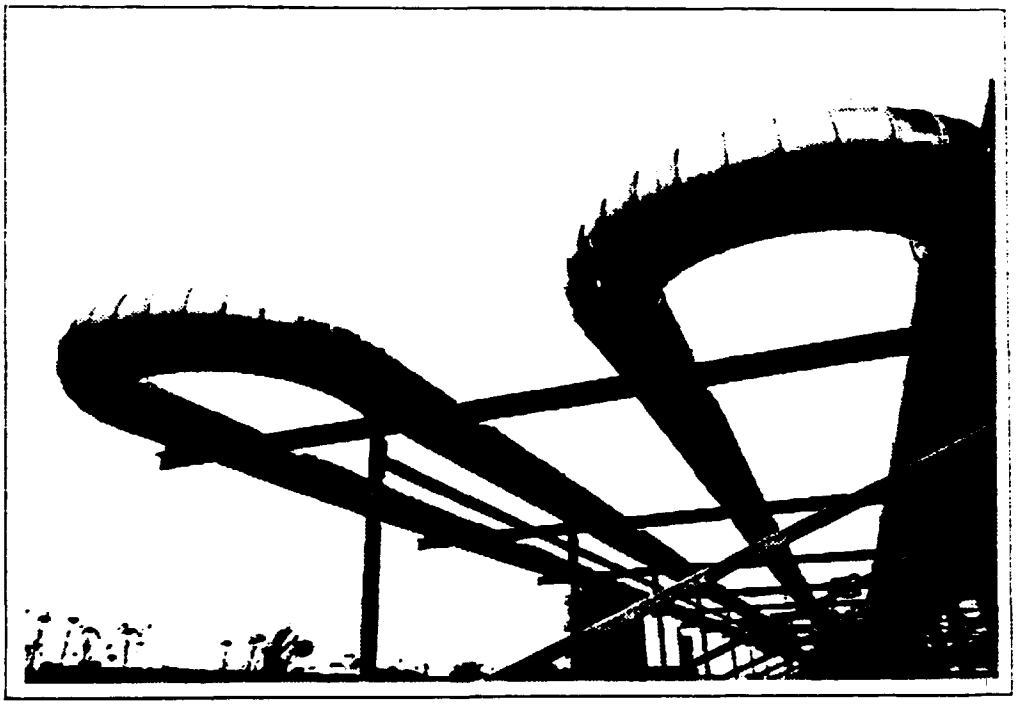

Fig. 5.3.1. Grog's view of the pipe reactor belonging to the Chemistry Section. This reactor is used for reclamation of polluted soil in a semi-industrial scale.

An attempt in the utilization of wheat straw can be used as an energy source when pretreated by wet oxidation. The wet oxidation is followed by enzymatic hydrolysis, which breaks down the very resistant glucosidic cellulose bonds. The yield of glucose was found to be more than 80%.

5.4 Chemical Analysis

Chemical analysis followed the main lines laid out in the previous yearly report and relied heavily on atomic absorption (AA), ionchromatography (IC), and inductively coupled plasma mass spectrometry (ICP/MS).

With a new grant from SJVF, an electrothermal vaporisation (ETV) unit linked to the ICP/MS instrument, will be in operation in early 1992 and creates the possibility for direct introduction of solid samples. Determination of NO_2^- in samples high in Cl^--content and analysis of phenol- containing water samples was successfully carried out with IC attached to a new detector already in function. New HPLC equipment will be permanently installed.

The wide variety of analytical problems, which have been solved, are reflected by the following activities: Participation in research projects including DCAR-projects on air pollution, syntheses of commercial organic products, plant uptake of toxic elements from stabilized soil industrial projects on improving methods for purification of soils and gasses, BCR reference material to EEC, geological formation with rare earths, and human nutrition.

Development of methods has continued to concentrate on trace analysis, the use of enriched non-radioactive isotopes, and performance of multielement analysis. The group is in an excellent position to select interesting portions of many national and international proposals in collaboration with a variety of partners.

A substantical part of the activities consisted of servicing the reactor DR 3, and other Riso Large Facilities plus commercial contracts.

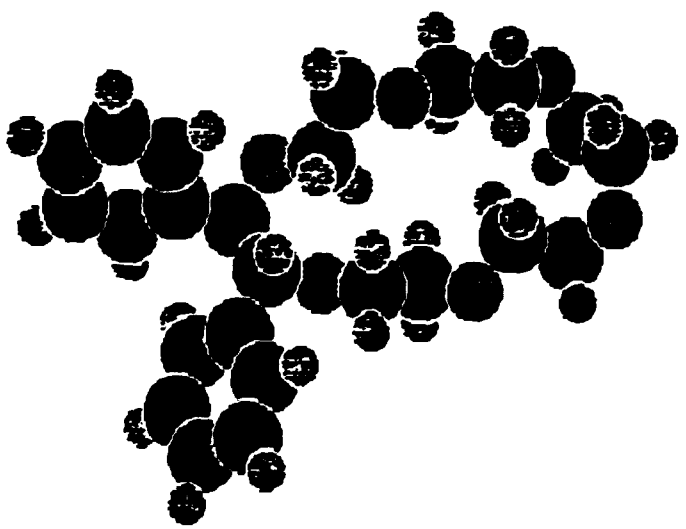

Fig. 5.6.1. An example of a so called CROWNETHER which selectively binds the potassium ion in the larger ring.

5.5 Syntheses

In recent years a substantial knowledge has accumulated concerning the non-traditional properties of organic molecules. New insight into the detailed structures, which are responsible for the optical-, electric-, magnetic- and catalytic-properties of these molecules, suggests new applications in sensors and other devices. This creates a need for organo-chemists with synthetic skills.

The group at Riso has, through the years, been involved in several commercial projects ranging from the preparation of isotopically labelled compounds, to the attachment of supramolecular units to both natural macromolecules and polymer surfaces. The group is, at present, working on the synthesis of catalytically active metal complexes, bonded to electroconducting organic polymers.

The group is also engaged in educational activities.

The activities of the group are closely related to those in the MODECS R&D Forum, in which both industrial firms and research institutions follow newer trends in basic and applied supramolecular chemistry and related topics.

5.6 MODECS

In 1991, MODECS arranged a one-day meeting on "Surface Modifications of Polymers and Biocompatibility" and a two-day meeting on "The Design of Novel Polymeric Materials with Special Properties", both with internationally renowned specialists as main speakers. Inspired, and partly financed by MODECS, a Ph.D.-study has been initiated. The study focuses on collective physio-chemical phenomena, which arise when functional units are immobilised on surfaces or macro-molecules. A deeper understanding of these events is of importance when designing and developing sensors, as well as in describing many interfacial phenomena.

During the last year, five new firms have become members of MODECS.

6 Ecology and Mineral Cycling

6.1 Ecological Halflives

The main sources of the present radioactive contamination of our terrestrial environment are global fallout from the nuclear weapons testing in the atmosphere and regional fallout from the Chernobyl accident.

The global fallout has been deposited mainly by precipitation. It originates from stratospheric inventories, which were created by the powerful thermonuclear test explosions carried out up to 1980. The radioactive debris in the stratosphere has a mean residence time of about 1 year. Hence the stratosphere no longer contributes to the global fallout. The Chernobyl accident in 1986 injected radioactive debris into the troposphere, where the mean residence time of fallout is only a few weeks.

In the last five years, therefore, we have had the opportunity to study the behaviour of two sources of radioactive contamination in the environment unperturbed by new inputs from the atmosphere. This has allowed us to study ecological halflives of "old" and "new" radiocaesium. The old comes from the global stratospheric fallout and the new from the Chernobyl activity.

The ecological halflife (T_E) of a radioactive pollutant is a combination of its environmental (T_M) and radioactive (T_R) halflives:

$$\frac{1}{T_E} = \frac{1}{T_M} + \frac{1}{T_R} \quad \text{i.e.}$$

the ecological halflife of a radionuclide in an environmental compartment is identical with its effective halflife. When the consequences of a given radioactive pollution are to be evaluated, it is necessary to know the ecological halflives of the pollutants in the various foods produced in the contaminated environment, because the dose to man depends on the infinite time integral of the radionuclide concentrations in foodproducts. If the initial concentration is C_o $Bqkg^{-1}$ and the ecological halflife is T_E years, the infinite time integral then becomes

$$C_o \times \frac{T_E}{\ln 2} \; Bqkg^{-1}y,$$

where $T_E/\ln 2$ is the ecological mean residence time of the radionuclide in the environmental sample in question. In practice, it appears that the environmental decay follows a number of exponential decays (a power function) rather than a single exponential decay. Just after the deposition of a radionuclide, there is a rapid decrease in the activity, due to environmental processes such as wash-off and weathering. Later, when the activity has penetrated the soil, it decays more slowly. The activity will be increasingly fixed to the soil and root-uptake will continue to decrease. The ultimate ecological halflife of a long-lived radionuclide will approach the radioactive halflife.

A comparison of what happens in the Danish and the Faroese environments is well suited for a study on the variation of ecological halflives, because the environmental conditions are so different in the two areas. The Danish agricultural ecosystem is intensively cultivated and the soils are low in organic matter and high in clay minerals, whereas in the Faroe Islands, the ecosystem is semi-natural, and the soils are generally low in minerals and high in organic matter. Fig. 6.1.1 and 6.1.2 illustrate the decay of Cs-137 in Faroese and Danish milk. It appears that the ecological halflives of the Chernobyl Cs-137 are shorter than those of the global fallout. The short ecological halflife of Chernobyl Cs-137 is due to a rapid decrease in the resuspension of Chernobyl Cs-137, a process that otherwise has been responsible for the continued direct contamination of the crops. We expect, however, that the ecological halflives of Chernobyl fallout in the coming years will approach those of the global fallout.

Remarkably, the ecological halflife of Cs-137 in Faroese milk is about half that in Danish milk. This is much shorter than in other seminatural ecosystems, e.g. in Norway and Ireland. We believe that this is due to a relative rapid penetration of the soil column. Run-off to the sea from the Faroese soils also plays a role. Measurements of Chernobyl Cs-137 in Faroese soils have shown that in 1991, only half of the originally deposited activity from 1986 remained in the upper 30 cm of the soil.

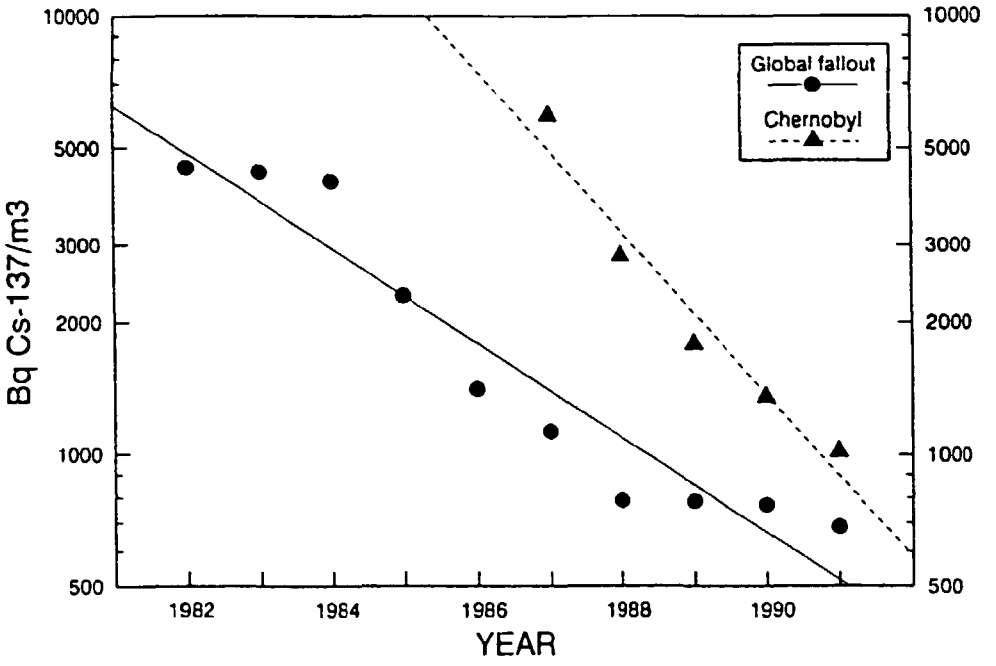

Fig. 6.1.1. Decay of Cs-137 in Faroese milk. The data are based on yearly means of monthly collected samples from 3 locations (Thorshavn, Klaksvig, Tvøra). The Chernobyl levels were calculated from Cs-134 and the theoretical ratio of Cs-134/Cs-137 in Chernobyl debris (= 0.55 at April 26, 1986). The ecological halflife of global fallout Cs-137 was 2.8 years and that of Chernobyl Cs-137 was 1.6 years.

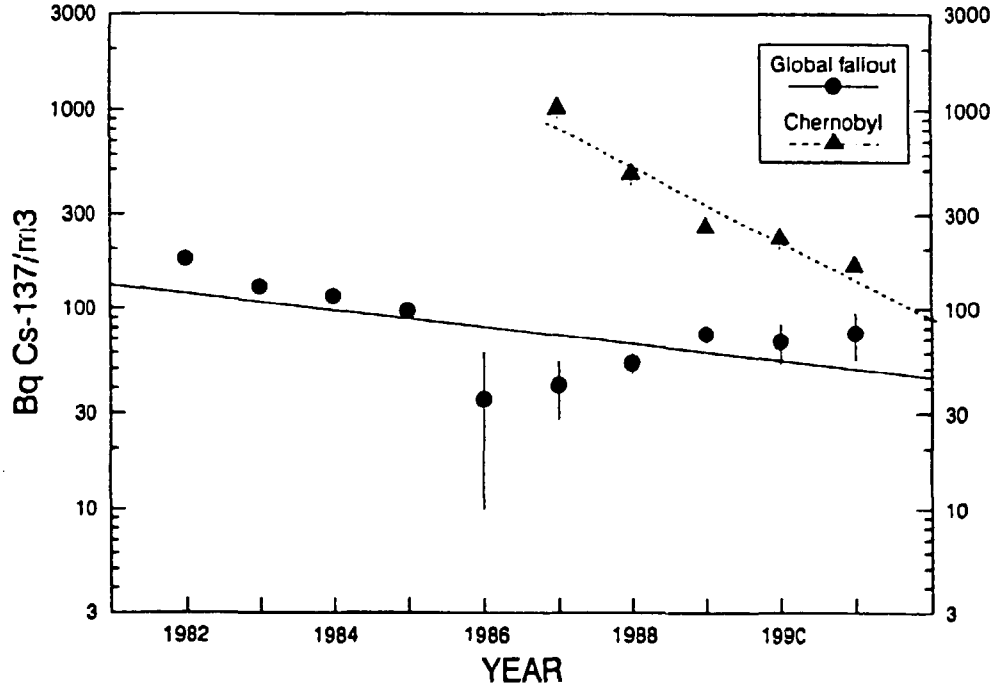

Fig. 6.1.2. Decay of Cs-137 in Danish milk. The data are based on monthly samples of dried milk collected in West Jutland (Videbæk). Cf. remarks to Fig. 6.1.1. The ecological halflife of global fallout Cs-137 was 7.1 years and that of Chernobyl Cs-137 was 1.6 years.

Fig. 6.1.3 shows the decay of another isotope, Sr-90, in Faroese and Danish milk. In this case, the source is global fallout only. It appears that Sr-90 has a longer ecological halflife than Cs-137 and that the ecological halflife of Sr-90 is longer in Danish than in Faroese milk. This has now led to higher Sr-90 concentrations in Danish milk than in Faroese, although the Faroese milk originally contained significantly more Sr-90 than the Danish.

It is important to remember, that the ecological halflife of a radionuclide in an environmental sample such as milk, depends on numerous factors. The composition of the cows fodder is e.g. of great importance. This composition may not only differ from place to place, but may also change with time. The longer ecological halflife of Sr-90 and Cs-137 in Danish, compared with Faroese milk, may be influenced by such factors. The production of Danish milk has, throughout the years, moved towards western Denmark, where the original contamination levels were higher. Faroese milk has in the same period, to an increasing extent, been based upon imported fodder, which has a lower Sr-90 content than that found in Faroese grass.

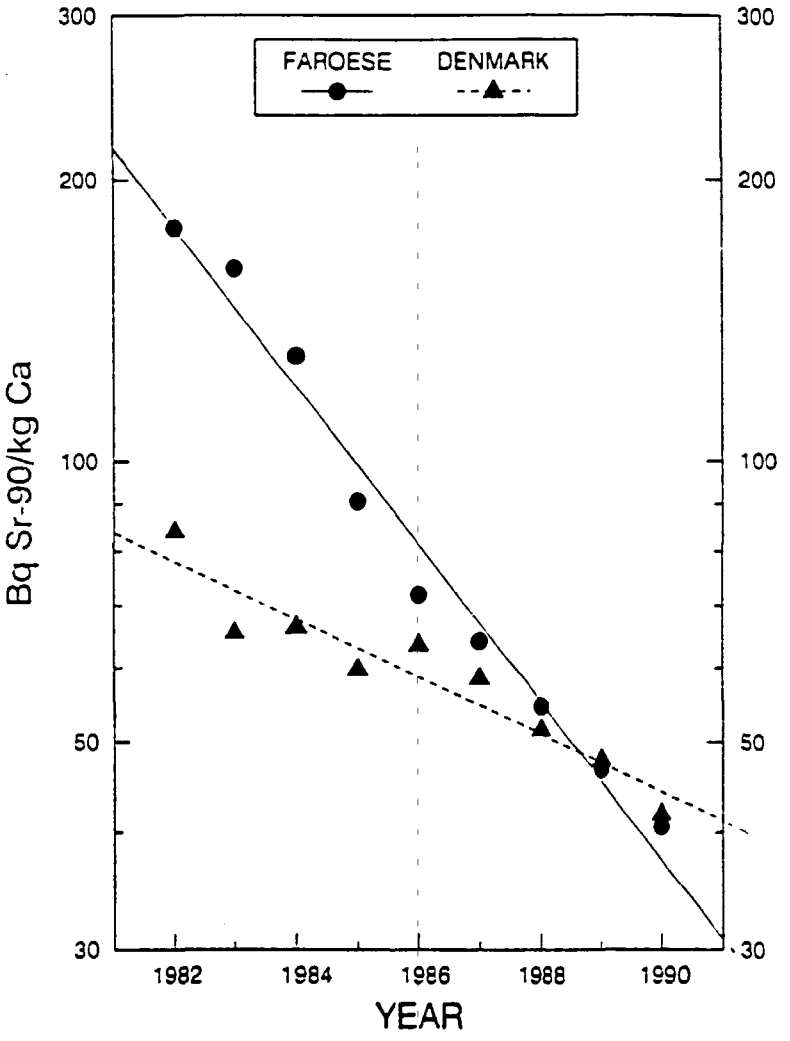

Fig. 6.1.3. Decay of Sr-90 in Danish and Faroese milk.
The ecological halflifes were 9.7 years in Danish milk and 3.5 years in Faroese.

6.2 Influence of Plant Variety on the Root Uptake of Radiocaesium

The long-term consequences of radioactive contamination in agricultural ecosystems depend partly on the transfer of radionuclides via roots from soil to vegetation. The fact that the transfer rates of radiocaesium from soil to plants in organic soils are significantly higher than those in mineral soils has been known since the 1960's from studies of nuclear weapons fallout. The objective of the present study, was to investigate the transfer of radiocaesium from organic and mineral soil to varieties of different crops, in order to identify statistically significant differences between varieties.

A pot experiment (Øhlensc' æger and Gissel-Nielsen, 9.1; Øhlenschlæger, 9.3) was started in 1988, where 56 pots were seeded with spring barley varieties (Golf, Apex, Anker and Sila), perennial rye grass varieties (Darbo and Patoro) and an Italian rye grass variety (Prego). Each crop was grown in two types of soil, a typical Danish sandy-loam from Riso, and an organic soil from Gävle, in Sweden, which received a large deposition of radiocaesium from the Chernobyl accident. The experimental design included four replicates in each group. Caesium-137 was experimentally added to the sandy- loam, and the organic soil, which was contaminated with Cs-137 from the Chernobyl accident, was supplied with Cs-134. The pots were seeded immediately after the isotopes were added to the soils.

The barley was harvested in August, and regarding the rye grass, five successive cuts were taken in the period from June to October. The experiment was repeated in 1989 and 1990 using the same pots. The upper 10-15 cm of soil in the pots were mixed in the spring, resown in May and the barley harvested in August. Statistical analyses were performed on the log-transformed concentration ratios (Bq per g plant relative to Bq per g soil, both dry weight), as the data were log-normally distributed.

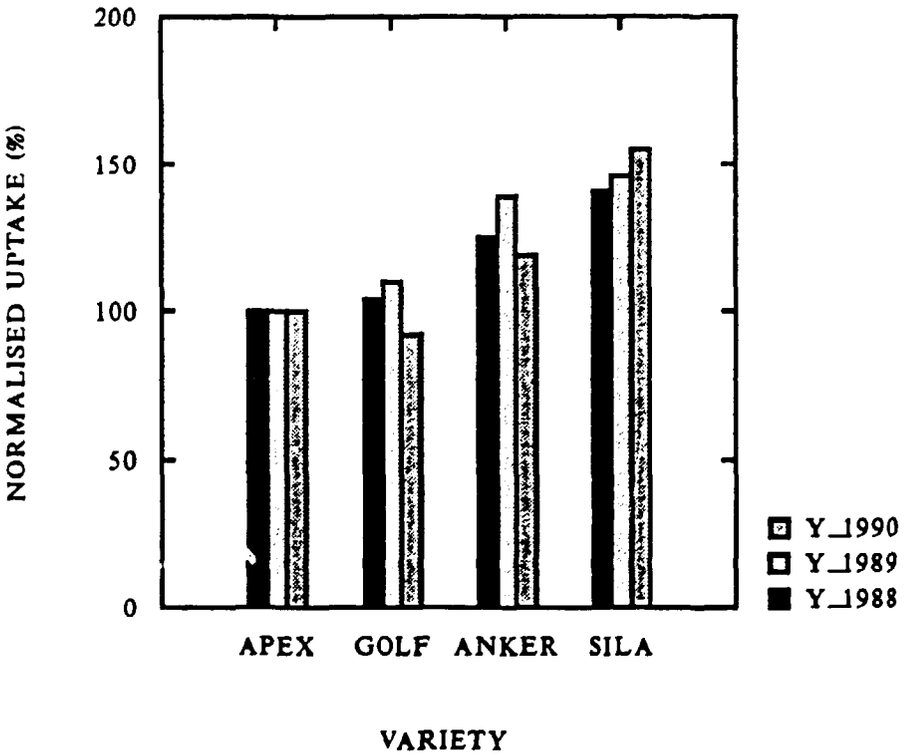

Fig. 6.2.1. Root uptake of radiocaesium in barley-grain varieties from the years 1988, 1989 and 1990 expressed relative to the uptake for the variety Apex. Every bar represents the mean of 12 results averaged across three soil/isotope groups with four replicates in each group.

The results for the barley grain are shown in Fig. 6.2.1. Analyses of the data show that there are statistically significant differences (30–40%) in root uptake for these barley varieties. The barley variety Sila has a significantly higher root uptake and the barley variety Apex, a significantly lower root uptake of radiocaesium in all experimental groups. Similarly, for the grass varieties, the Italian rye grass was identified as the one with the relatively highest uptake of caesium for all the groups. The uptake was almost a factor of two higher for the Italian rye grass than for the other two varieties, averaged over the growing season.

The results thus indicate, that it is possible to reduce the radiological consequences after a nuclear accident by efficient planning of countermeasures. These could comprise changes of agricultural practices towards the use of plant species and varieties with low sensitivity to radioactive contamination.

6.3 Variation in Trace Element Loss Rates from Baltic Mussels

Mytilus edulis

The mussel, *Mytilus edulis*, is probably the most widely sampled bioindicator organism in marine monitoring programmes for various pollutants, mainly radionuclides and metals. One of the reasons for its popularity is its wide distribution. It is found from temperate to arctic waters, from fully marine areas to estuaries showing permanent salinities as low as 3–5 ‰. It is furthermore quantitatively dominating in several low-water environments, *e.g.* in large parts of the Baltic sea. Another interesting characteristic of Mytilus relevant to its metal and radionuclide metabolism, is its filter feeding.

There are several advantages of including biological indicator organisms, like mussels, in monitoring programmes: *biomagnification* improves detection limits, *time integration* smooths fluctuating environmental levels of pollutants as the result of long-term retention, and the sensitivity is greatest for the most *bioavailable* elements and chemical species. These advantages are, however, not without costs. By introducing biological samples in a monitoring programme, one inevitably introduces a variation with several environmental parameters, such as season and salinity. It is important to know this variation in bioindicator response, as insignificant differences between data sets could otherwise be misinterpreted. Nevertheless, the variation does not prohibit a meaningful use of the bioindicators. In addition to the "applied" aspects of improving the use of mussels in bioindicator programmes, the study of trace element cycling in marine and estuarine environments, including its variation, forms an important part of our general understanding of nature's "household".

Figure 6.3.1. Mussel experiment in the Baltic at Oscarshamn. The experimental animals, used in a long term loss study, are situated in the floating cages.

Two long-term *in situ* loss studies with 12 radioactive trace elements in two Baltic *Mytilus edulis* populations were made at the Forsmark Biotest facility, 120 km north of Stockholm.

and at Oskarshamn, 250 km south of Stockholm, respectively. Results showed large differences between biological half-lives and retentions at the two sites (Dahlgaard, 9.1). At least part of these differences may be explained by low food availability. It is suggested that "starving" mussels, not having access to sufficient food to sustain growth, show a prolonged retention of trace elements; i.e. when the energy metabolism is reduced, the rate of trace element turnover is also reduced. Such a coupling between energy metabolism and trace element metabolism includes not only biologically active elements such as Co, Zn, Mn and Ag, but also elements with no known biological function, such as Pu, Am, Cm, Ce and Eu. Under normal food and growth conditions, a dilution of the accumulated trace elements, due to new growth, may be more important in determining trace element concentrations than the actual loss of metals or radionuclides from the animals. It should, therefore, be expected that metal and radionuclide concentrations might be much higher in a starving mussel population than in a fast growing one. This is very important for the interpretation of mussel data in bioindicator monitoring programmes.

6.4 Fish Ecotoxicology

What happens to larval or small post-larval fish that are set out in the environment to secure a natural population? Do they ever reach maturity in amounts large enough to influence the fishery? What is the effect of the enhanced ambient temperatures in a thermal effluent from an electricity generating plant?

Stockings of elvers (Anguilla anguilla) were made in 1982 and 1984 in the cooling water effluent area from the Swedish nuclear power plant at Oskarshamn (unit III, 1060 MWe) on the Baltic coast south of Stockholm. The elvers were tagged with ^{155}Eu and ^{152}Eu, respectively; recaptures were made from 1983 to 1989, based on samplings at monthly intervals. At our laboratory, about 10 cm of backbone from each animal was removed, ashed and counted for γ-radioactivity, first with a NaI crystal and then, if any europium was found, further verified by using a Ge-Li detector. Detection of tagged eels was found to be possible for at least 7 years after stocking. Originally, the tagged elvers weighed on the average 0.21 g; the largest detected eel weighed 447 g (Anderson, *et al.*, 9.1). This showed a remarkable degree of europium reabsorption from the original cartilage by developing eel bone.

Fig. 6.4.1. An eel is seen compared to its appearance for years earlier, when it was a few months past the elver stage. Even though it has grown by a factor 300, it has retained most of its original radioactive label.

At the end of the study (Anderson, *et al.*, 9.1) 3.5% and 1.3%, respectively, of the two stockings had been recaptured. Although the area was open to the sea, the heated water (10°C above normal) evidently induced many of the eels to remain near the power plant during their juvenile life. In the spring of 1987, as much as 53% of the total capture were tagged eels. The average growth rate was 7 cm/year during the first five years, which is significantly larger than normally expected in Swedish waters. There was no evidence of negative impact on body condition (weight/length-cubed) or fat content, relative to control eels at Halmstad on the Swedish west coast.

It could generally be concluded that thermal discharge areas in temperate Scandinavian waters evidently favour eel growth and development. Radioactive europium has been shown to be an excellent long-term mark for elvers.

6.5 Rimi Field Station

In 1990, Riso National Laboratory initiated an interdisciplinary research, "Riso's Integrated Environmental Project" (RIMI). The project is aimed at the study of pathways, processes and effects of nitrogen compounds derived from human activities. The project focusses on the terrestrial environment. Deposition of nitrogen compounds emitted into the atmosphere plays an important role in both acidification and eutrofication of ecosystems, and there is a substantial need for more precise information on both qualitative and quantitative aspects of the problem. RIMI involves scientists from the Environmental Science and Technology Department, as well as scientists from the Meteorology and Wind Energy Department and Optics and Fluid Dynamics Department.

A field station was established in 1990-1991 in order to study the atmospheric chemistry of nitrogen compounds under field conditions and the exchange of nitrogen compounds between the atmosphere and terrestrial ecosystems. The field station is placed in a conventional Danish agricultural area two kilometers from the Riso National Laboratory. The field station is comprised of a ten meter high meteorological mast placed in the middle of a cereal field with an instrument hut placed at the margin of the field. The mast and the hut are connected with underground wires for power supply and data transfer. The data acquisition system is connected to the data network at Riso. The field station is equipped with instruments for meteorological parameters and chemical compounds. The use of the field station is open to other institutions, provided that a reasonable cooperation on projects of mutual interest with RIMI is ensured.

In addition to the basic instrumentation, several other instruments connected to special projects are placed at the station for shorter or longer periods.

Meteorological parameters and concentrations of ozone, nitrogen dioxide and sulphur dioxide have been monitored continuously since February 1991. The station has been the basis for studies of fluxes and chemical composition of aerosols.

Basic instrumentation at field station:

PARAMETER	INSTRUMENT	PARAMETER	INSTRUMENT
Wind speed	Cup anemometers	Rain	Tipping bucket
Wind direction	Wind vane	Aerosol conc.	LP impactor
Wind fluctuation	Sonic	Aerosol flux	Optical counter
Temperature	PT 100 and 500	Ozone Flux	Chemilumin.
Humidity	Hygrometer	NO_2 and NO flux	Chemilumin.
Water vapour flux	IR-hygrometer and sonic	Ozone conc.	DOAS
		NO_2 conc.	DOAS
Radiation	Radiometer	SO_2 conc.	DOAS
Surface temperature	IR-Thermometer		

The station also serves as a background station for air pollution in Copenhagen (by the National Environmental Research Institute) and has been the site for an intensive measuring campaign in August 1991 within the EUROTRAC-TOR project, dealing with tropospheric ozone and related chemical reactions. The Danish TOR-project is carried out in cooperation with the National Environmental Research Institute.

6.6 Radioactive Tracers in the Greenland Sea

Several water masses of different origin can be distinguished in the Greenland Sea. Knowledge of the origin of these water masses is of importance in the understanding of their role in the World Ocean circulation, including deep water formation. The measurement of different

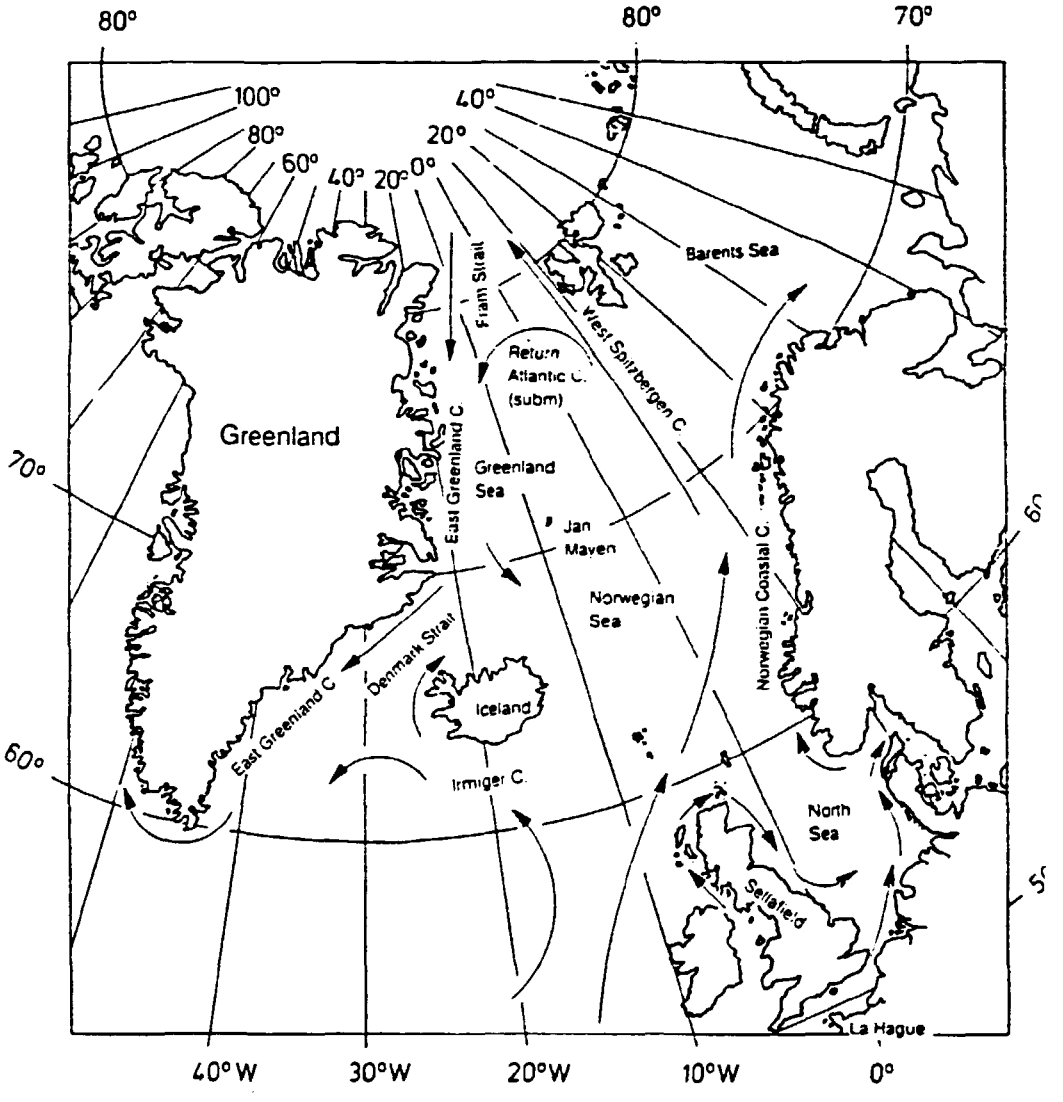

Fig. 6.6.1. Selected currents of particular importance for the transport of European discharges to the Greenland Sea. Part of the low concentrations of manmade radioactive elements in the Greenland Sea and the East Greenland Current have been identified as English discharges. The transport route, from the English west coast at Sellafield goes through the North Sea, the Norwegian Coastal Current and the West Spitzbergen Current to the East Greenland Current.

tracers, including a variety of man-made radionuclides, can provide a major contribution to this understanding. In the Greenland Sea Project, we have utilized the nuclides ^{137}Cs, ^{134}Cs, and ^{99}Tc.

The main sources of ^{99}Tc in the Greenland Sea are controlled discharges from Sellafield (formerly Windscale) into the Irish Sea and, to a lesser extent, La Hague discharges into the English Channel. The contribution from global fallout, to the measured ^{99}Tc concentration in the surface waters of the East Greenland Current, has previously been estimated at only 10–20%. The concentrations of ^{99}Tc are highest in the part of the East Greenland Current closest to the Greenland coast, i.e. in the Polar water (Dahlgaard *et al.* a, 9.2)

The discharges of ^{99}Tc from Sellafield peaked in 1978, and dropped by an order of magnitude by 1981. The transport time from Sellafield to the East Greenland Current was previously estimated to be ~7 years. Presumably, the La Hague discharges reach the area two years faster, but Sellafield was still the dominant source of ^{99}Tc in the Greenland Sea in 1988.

Assuming that the Chernobyl accident was the only significant contributor to the concentration of ^{134}Cs in the Greenland Sea in 1988, the appearance of Chernobyl caesium in the intermediate water at 80 – 300 meters (Dahlgaard *et al.* b, 9.2) indicates a significant contribution in surface water, having an age of only two years. The origin of this surface water was probably the Norwegian Coastal Current or the West Spitzbergen Current. Equivalent measurements of technetium-99 from the European discharges during the 1970's and 1980's are consistent with a very high water renewal rate in the studied part of the Greenland Sea.

The results show that measurements of radioactive tracers give a valuable supplement to the traditional oceanographic measurements by introducing a time factor following geographically well-established release peaks. The release of ^{99}Tc from Sellafield in the late 1970's was one such peak; the release of ^{137}Cs from the Chernobyl accident in 1986 was another.

6.7 Radioecological Cooperation with the former USSR

In the spring of 1991 a "skim and burial" plough, developed at Riso in collaboration with the "Bovlund" plough factory, Jutland, Denmark, was put through a final test. (Fig. 6.7.1, next page). The plough can remove a contaminated top-layer of approximately 5 cm of soil and bury it beneath some 45 cm soil, without inverting the 5–45 cm layer in between. This is done to avoid less fertile subsoil being brought to the surface and at the same time, allowing normal tilling procedures to be carried out without contaminating the 20–25 cm layer of tilled soil.

Three benefits from using this plough after a surface contamination can be identified as 1) a considerable reduction in doserate over the surface, 2) a lower uptake of radioisotopes to plants and 3) a considerable reduction of resuspension, as the contaminated soil, once buried, will not be resuspended in the following tilling procedures.

The plough is to be used in connection with countermeasures after the Chernobyl accident.

Fig. 6.7.1.

7 Other Activities

7.1 Decontamination Strategies for Urban Areas

Studies at Gävle (Sweden) demonstrated that many urban surfaces, such as roof tiles and concrete, have a considerable potential for intercepting and retaining radiocaesium fallout from the Chernobyl accident.

The interception by such surfaces is not in itself surprising, since caesium (a cation) would be expected to ion exchange with sodium, potassium and calcium (also cations), which are known to occupy anionic adsorption sites on the surfaces of almost all urban minerals. What was surprising however, was the strong retention of absorbed caesium on these surfaces, even after extensive decontamination treatments. (Roed *et al.*, 9.2; Anderson, 9.3)

The ratios of nuclide concentrations in run-off water, compared with those in rain water, give an estimate of the various interception potentials. Eternite, a common roofing material, showed a high affinity, absorbing 80% of the deposited material, whereas silicon-treated surfaces had an uptake of only 50%.

Shortly after deposition, 40–80% of the initially deposited caesium remained on paved areas. Two years later, 5–20% was left, the percentages depending strongly on traffic. A portion of 20–70% remained on roofs.

A strategy for the decontamination of an urban area was set up. It was found that the removal of trees and the decontamination of gardens are efficient and inexpensive means of achieving very significant reductions in dose. Such measures would rate highly on a list of priorities. Street cleaning is also cost-effective.

Although roofs are important contributors to dose, the cost of cleaning them is so great, that roof decontamination would not rank highly on a priority scale. Walls contribute little to total dose and are expensive and difficult to clean. Their decontamination would, therefore, carry a very low rating on a list of priorities.

7.2 Photochemistry and Photophysics

The general scope of the activity has been expanded considerably. In particular, the techniques of nanosecond laser flash photolysis in combination with time-resolved absorption spectroscopy on the one hand, and fluorescence lifetime spectroscopy on the other, have been added to the experimental facilities. This has been possible through considerable support by the Danish Natural Science Research Council. It is also the reason for a change of the name of the group (previously Raman group).

Most of the previous studies were continued. They all concern investigations of the potential energy surfaces of electronic excited states, or free radicals of organic molecules of basic and applied interest. All studies were carried out in close collaboration with Dr F.W.Langkilde, Royal Danish School of Pharmacy.

1,3,5-Hexatriene (HT) and related compounds are still the most important area of research. In particular, five full scale papers on spectroscopic and photochemical studies of HT, both in solution and in the gas phase were completed. New studies have been initiated on specially synthesized HT which is "locked" at the central position and is therefore prevented to isomerize. Work on the triplet state of stilbene continues. Both these projects were carried out in international collaboration with laboratories in Italy (Professor G. Orlandi) and The Netherlands (Drs A.M. Brouwer and H.J.C. Jacobs).

A study of intramolecular proton transfer was completed in collaboration with the Institute of Physical Chemistry of the Polish Academy of Sciences (Dr A. Mordzinski).

The benzyl radical, being of fundamental interest in atmospheric and combustion chemistry, was studied in collaboration with the Industrial Chemistry Research Institute, Poland (Dr K. Bajdor).

Macrocylic compounds of importance in molecular switches were studied in collaboration with CISMI, Copenhagen University (Professor K. Bechgaard).

Collaboration with Dr O.S. Mortensen, Odense University, in the field of resonance Raman spectroscopy continues.

7.3 Risø High Dose Reference Laboratory (HDRL)

In October 1991, the Riso High Dose Reference Laboratory became recognized by the Danish National Agency of Industry and Trade as an accredited Testing and Calibration Laboratory with the registration No. 266. The accreditation was issued under the Danish Accreditation Scheme (in Danish: Dansk Akkrediterings Ordning), which is administered by the Danish Institute of Fundamental Metrology. International recognition of the Danish Accreditation Scheme is assured through its membership of the Western European Calibration Cooperation, WECC. This organization assures mutual recognition of certificates and reports which are issued by testing and calibration laboratories, accredited in the member contries. Signatories of this WECC agreement are:

Denmark	Danish Accreditation Scheme
France	Bureau National de Métrologie, BNM
Finland	Centre for Metrology and Accreditation
Germany	Deutscher Kalibrierdienst, DKD
Italy	Servizio di Taratura in Italia, SIT
Netherlands	Nederlandse Kalibratie Organisatie, NKO
Switzerland	Swiss Calibration Service, SCS
Sweden	Swedish Board for Technical Accreditation, SWEDAC
United Kingdom	National Measurement Accreditation Service, NAMAS

The High Dose Reference Laboratory is working for the radiation processing industry. Its services include irradiation of dosimeters and samples to specified doses, the issue of calibrated dosimeters, and measurements of absorbed dose in facilities and products. The range of absorbed dose is specific for each service, but in general, it is from one kGy and higher. Measurements and irradiations, at both cobalt-60 photon and 10 MeV electron facilities, are covered by the services of the High Dose Reference Laboratory. During 1991 - before and after the official accreditation was issued - a total of 75 reports and 34 certificates were issued.

In order for a laboratory to obtain accreditation, it must demonstrate that its measurements are traceable to a national standard at the primary standard level. Some confusion exists about the standard hierarchy. Actually, any standard can be chosen as the national standard, but in order for it to be primary, its response must be derived from fundamental physical constants. The HDRL does not maintain its own primary standards in the field of radiation dosimetry. We must therefore look elsewhere to calibrate our secondary standards, and we have chosen to go to the National Physical Laboratory in England. By this calibration - and by auditing the calibration - we may say that the HDRL dose measurements are traceable to the NPL.

The High Dose Reference Laboratory operates according to a European standard: EN 45001, General Criteria for the Operation of Testing Laboratories, and to the OECD Rules for Good Laboratory Practice. These documents are part of the many standards and guidelines that will harmonize European industry and

trade in preparation for the Single Market which will be in effect by 1993.

Without accreditation, a calibration or testing laboratory may find it difficult to get its results and certificates recognized, so customers may therefore be reluctant to buy its services. It is, therefore, good for business to become accredited, and also good for the measurements. All procedures and practices must to be reviewed and documented, uncertainties have to be accounted for and calibrations maintained. It all leads to better measurements and fewer mistakes, thereby providing assurance of the quality control of the laboratory.

Industrial irradiation has continued on the 10 MeV electron accelerator. Products have been irradiated for sterilization of medical equipment, modification of polymers, and to a limited extent, also for the decontamination of spices. Special products and samples have been irradiated both on the 10 MeV accelerator, the 400 keV accelerator and on the cobalt-60 facilities.

The 10 kCi facility located in the section for Plant Biology, had its eight sources replaced with new ones, which were made at Riso. The eight old sources were, as usual, transferred to the gamma cell in the Chemical Reactivity Section.

A second gamma cell, which for many years has been on loan to the State Serum Institute, was returned to Riso and is now installed in the hall in the Chemical Reactivity Section. This gamma cell (labelled No. 2) also had its source strength increased with the replacement of two sources.

The closing of the Riso Hot Cell means that cobalt-60 sources can no longer be produced at Riso. It is possible to obtain new sources for Riso's gamma facilities abroad, but as the next source replacement is scheduled for 1996 or 1997, no details have yet been worked out.

8 Large Facilities

8.1 10 MeV Linear Electron Accelerator

The Riso linear accelerator was manufactured in 1975 by Haimson Research Corp. Electrons are accelerated by an electromagnetic microwave field with a frequency of 2856 MHz. The accelerator is used for radiation sterilization, plastic modification, food treatment, radiation hardness testing, semiconductor modification and initialization of chemical processes in kinetic investigations. Products are irradiated on a conveyor belt with electrons striking above. Maximum product size is normally 80 x 60 x 30^3 (l w h), but other sizes may be accommodated. The maximum height depends on the product density.

8.2 Pilot Plant for Metal Extraction

A complete and selfcontained pilot plant was established at Riso in 1981 initially to handle metal extraction under alkaline and neutral conditions from a variety of ore types and minerals.

The heart of the plant is a 1200 m long pipe reactor which makes possible continuous treatment of suspensions at 280°C and 100 bar. The pilot plant has since intermittently been used to implement our wet oxidation process on a semiindustrial scale.

8.3 Experimental Farm

DYSKÆRGAARD is an experimental farm with approximately 120 hectares of arable land. The experimental farm is partly used for field experiments, and partly for grain and beef production.

8.4 Open Top Chamber Facility

In collaboration with the National Environmental Research Institute and University of Copenhagen the Department operate a large Open Top Chamber facility situated at Riso. The facility consists of 19 large chambers (3.5 meters in diameter) and 20 small chambers (1.5 meters in diameter).

The small chambers have been equipped with lysimeters for water and nutrient balance studies, and for measuring nutrient leaching from the soil profiles.

The chambers are used for short- and long--term studies of the effects of air pollution on crop plants and trees.

9 Publications

9.1 Refereed Journals and Books

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Pedersen, L.H., Characterization and partial purification of 1.3-ß-glucan synthase from barley leaves. Annual Meeting of The American Society of Plant Physiology, Albuquerque, New Mexico, USA, July 28 - August 1, 1991.

Pedersen, L.H., Characterization and partial purification of 1.3-ß-glucan synthase from barley leaves. Biokemisk Forenings Årsmode, Fuglsocentret, October 24-26, 1991.

Pedersen, L.H., Callose synthesis in barley leaves. Statens Plantevæmscenter, Biotekhnologigruppen, Lyngby, November 8, 1991.

Petersen, L., Anvendelse af RFLP i resistensforædlingen. Den Kgl. Veterinær- og Landbohojskole, February 28, 1991.

Rasmussen, S.K., Peroxidase gene expression in seed and leaves of barley. Symposium on "Enzymes in Plant Pathogen Resistance", Danish Biochemical Society, Copenhagen, March 12, 1991.

Rasmussen, S.K., Cloning and characterization of peroxidase genes from barley. Meeting on Barley-Pathogen interaction organized by David Collinge for the Nordic Research Council, April 15, 1991.

Rasmussen, S.K., Molecular cloning, nucleotide, amino acid and carbohydrate sequence of barley peroxidases; Developmental and tissue-specific expression. Instituto Biosintesi Vegetali, CNR Milano, Italy, December 19, 1991.

Rasmussen, S.K., Johansson, A., Theilade, B., Organization and expression of genes coding for barley seed peroxidases. Tucson, Arizona, USA, October 6-11, 1991.

Roed, J., Effectiveness of a Skim and Burial Plough. Workshop on the Relative Effectiveness of Agricultural Countermeasures Techniques. "REACT", Brüssel, October 1-4, 1991.

Roed, J., Ploughing as an effective countermeasure. Erosoil - research meeting, Cadarache, France, June 26, 1991.

Roed, J., Deposition and resuspension of radioactive material in Pripjet. Dorstroj teknika, Minsk, July 15, 1991.

Roed, J., 1. Deposition on and run-off from radioactive material from surfaces. 2. Strategies on decontamination. Workshop on Reclamation of Radioactive contaminated area, Rastaborg, Sweden, April 22-24, 1991.

Roed, J., Andersson, K.G., Development of Countermeasures from observations on contaminated soils. XXVII-CSI Pre-Symposium: Measurements of Radionuclides after the Chernobyl Accident. Bergen, Norway, June 6-8, 1991. (Invited)

Rosendahl, L., Exchange of metabolites across the peribacteroid membrane in pea root nodules. Umeå, Sverige, October 2, 1991.

Rosendahl, L., Involvement of the peribacteroid space of pea nodules in exchange of compounds between the symbionts. Int. Symbiosis Congres, Jerusalem, Israel, November 19, 1991.

Rosenkrands, I., Rasmussen, S.K., Svendsen, I., Hejgaard, J., Serpins of barley grains with potential inhibitory activity. Biokemisk Forenings årsmøde, Fuglsocentret, October 24-26, 1991.

Sehested K, Ozone-water-phase chemistry in relation to the troposphere. Department Seminar, Riso, December 4, 1991 (in Danish).

Sehested, J., Nielsen, O.J., Atmospheric chemistry of HCFCs and HFCs studied at Riso. At the CEC/EUROTRAC Atmospheric Chemistry Discussion Meeting, York, September 23-25, 1991.

Theilade, B., Rasmussen, S.K., Karakterisering og mapping af bygperoxidase BP 2A-genet. Biokemisk Forenings årsmøde, Fuglsocentret, October 24-26, 1991.

Wilbrandt, R., The potential energy surface of the T_1 state of 1,3,5-hexatrienes. Invited lecture at the XVth International Conference on Photochemistry, Paris, July 28 - August 2, 1991.

Wilbrandt, R., Triplet states of polyenes. Invited lecture at the International Meeting on Time-resolved Vibrational Spectroscopy of Biological and Related Molecules, Nara, Japan, June 8, 1991.

Wilbrandt, R., The potential energy surface of the T_1 state of 1,3,5-hexatrienes and methylated derivatives: A survey of present knowledge. Invited lecture at the Fifth International Conference on Vibrational Spectroscopy, Tokyo, Japan, June 2-7, 1991.

10 Publications in press

Anastasi, C., Broomfield, M., Nielsen, O.J., Pagsberg, P., "The reactions of CH_2SH radicals with O_2, NO and NO_2". – J. Chem. Phys.

Andersen, L., Jørgensen, J. Helms, Mlo aggressiveness of barley powdery mildew. – Norwegian Journal of Agricultural Sciences.

Bertelsen, F., Jensen, E.S., Gaseous nitrogen losses from field plots grown with pea (*Pisum sativum*) or spring barley (*Hordeum vulgare*) estimated by ^{15}N mass balance and acetylene inhibition technique. – Plant and Soil.

Boëtius, I., Boëtius, J., Hansen, H.J.M., Studies on lipid synthesis by incorporation of ^{14}C-acetateduring experimental maturation of silver eels, Anguilla anguilla. – Dana 9.

Borbye, L., Linde-Laursen, I., Christiansen, S.K., Giese, H., The chromosome complement of *Erysiphe graminis* f.sp. *hordei* analysed by light microscopy and field inversion gel electrophoresis. – Mycological Research.

Brodersen, K., Nilsson, K., Pores and Cracks in Cemented Waste and Concrete. – Cement and Concrete Research.

Dahlgaard, H., Boelskifte, S., "SENSI": A Model describing the Accumulation and Time-Integration of Radioactive Discharges in the Bioindicator *Fucus vesiculosus*. – J. Environ. Radioactivity 15.

Giese, H., The use of RFLP markers in barley breeding. – In: Barley Genetics VI. Helsingborg, Sweden.

Giese, H., Replication of DNA during barley endosperm development. – Canadian Journal of Botany.

Jakobsen, I., Abbott, L.K., Robson, A.D., External hyphae of vesicular-arbuscular mycorrhizal fungi associated with *Trifolium subterraneum*. 1: Spread of hyphae and phosphorous inflow into roots. – New Phytologist 120.

Jakobsen, I., Abbott, L.K., Robson, A.D., External hyphae of vesicular-arbuscular mycorrhizal fungi associated with *Trifolium subterraneum*. 2: Hyphal transport of ^{32}P over defined distances. – New Phytologist 120.

Jakobsen, I., Phosphorous transport by external hyphae of vesicular-arbuscular mycorrhizal. – In: Mycorrhizal in Ecosystems (eds I.J. Alexander, J.H. Fitter, D.H. Lewis and D.J. READ); CAB International.

Jensen, E. S., The release and fate of nitrogen catch crop material decomposing under field conditions. – Journ. of Soil Sci. 43.

Jensen, H.P., Christensen, E., Jørgensen, J. Helms, Powdery mildew resistance genes in 127 Northwest European spring barley varieties. – Plant Breeding.

Jensen, J., Co-ordinator's report: Chromosome 5. – Barley Genetics Newsletter 20.

Johansson, A., Rasmussen, S.K., Harthill, J., Welinder, K.G., cDNA, amino and carbohydrate sequence of barley seed peroxidase BP 1. – Plant Mol. Biol.

Jørgensen, J. Helms, Summary of poster session X: Disease Resistance and Pest Management. – Barley Genetics VI vol. 2.

Jørgensen, J. Helms., Multigene families of powdery mildew resistance genes in locus *Mla* on barley chromosome 5. – Plant Breeding.

Jørgensen, J. Helms, Co-ordinator's report: Disease and pest resistance genes. – Barley Genetics Newsletter 20.

Jørgensen, J. Helms, Previous achivements (in the ECP/GR barley programme 1980-1991). – In: International Crop Network Series. Report of an International Barley Working Session.

Jørgensen, J. Helms, Discovery, characterization and exploitation of Mlo powdery mildew resistance in barley. – In: R. Johnson and G.J. Jellis (eds), Breeding for Disease Resistance, Kluwer Acad. Publ., Dordrecht. BSPP Symp., Newcastle, England, December 18, 1991.

Jørgensen, J. Helms, Sources and genetics of resistance to fungal pathogens. – In: Barley: Genetics, Molecular Biology and Biotechnology, Shewry, P. (ed.). CAB International, UK.

Jørgensen, R.B., Andersen, B., Andersen, J.M., Effects and characterization of the conditioning medium that increase colony formation

from barley (*Hordeum vulgare* L.) protoplasts. – J. Plant Physiol.

Linde-Laursen, I., Giemsa C-banded karyotypes of cultivated and wild barley (*Hordeum vulgare* s.l.) – Barley Genetics Newsletter 20.

Linde-Laursen, I., Barley × rye hybrids elimina-ting accessory chromosomes of rye. – Hereditas.

Linde-Laursen, I., Bothmer, R. von, Jacobsen, N., Relationships in the genus *Hordeum*: Giemsa C-banded karyotypes. – Hereditas.

Lorenzetto, P., Bjergbakke, E., Hickel, B., "Water radiolysis under NET conditions". ISFNT 2, Karlsruhe. Proceedings.

Lührs, R., Nielsen, K., Microspore cultures as donor tissue for the initiation of embryogenic cell suspensions in barley (*Hordeum vulgare* L.). – Plant Cell, Tissue and Organ Culture.

Markert, F., Nielsen, O.J., "Rate constants for the reaction of OH radicals with 1-Chloroalkanes at 295 K". – Chem. Phys. Lett.

Nielsen, T., Pilegaard, K., Jensen, A.B., Occurrence and sources of atmospheric polycyclic aromatic hydrocarbons at an international airport. – Polycyclic Aromatic Compounds.

Nielsen, O.J., Ellermann, T., Bartkiewicz, E., Wallington, T.J., Hurley, M.D., "UV absorption spectra and mechanisms of the self reaction of CHF_2O_2 radicals in the gas phase at 298 K". – Chem. Phys. Lett.

Nielsen, K. A., Hansen, I.B., Appearance of extracellular proteins associated with somatic embryogenesis in suspension cultures of barley (*Hordeum vulgare* L.). – J. Plant Physiol.

Pilegaard, K., Jensen, E.S., Foliar uptake of NO_2 in barley. Proceedings of the COST/BIATEX Workshop, Delft, Holland, October 1991. – CEC Air Pollution Research Report.

Pilegaard, K., Atmospheric Heavy Metal Deposition in Northern Europe 1990.

Rasmussen, U., Giese, H., Mikkelsen, J.D., Induction and purification of chitinase in *Brassica napus* L. ssp. *oleifera* infected with *Phoma lingam*. – Planta.

Rasmussen, S. K., Johansson, A., Nucleotide sequence of a cDNA coding for the barley seed protein CMa: an inhibitor of insect α-amylase. – Plant Molecular Biology.

Rosendahl, L., Dilworth, M.J., Glenn, A.R., Exchange of metabolites across the peribacteroid membrane in pea root nodules. – J. Plant Physiol.

Skou, J.P., Identifikation og bevaring af arvelige egenskaber. – Växtskyddsnotiser.

Skou, J.P., A series of xerophilic *Chrysosporium* species. – Mycotaxon 43: 237–259.

Sommer, S.G., Jensen, E.S., Schjørring, J.K., Leaf absorption of gaseous ammonia after application of pig sherry on sand between rows of winter wheat. – In: Proceedings of COST/Biosphere Atmosphere, Exchange. Joint Workshop, October 28–30, 1991, Delft.

Sørensen, E., Bjerre, A.B., Combined Wet Oxidation and Alkaline Hydrolysis of Polyvinylchloride. – Waste Management.

Sørensen, E., Bjerre, A.B., On the stabilisation of Niobium(V) solutions by Zirconium(IV) and Hafnium(IV). – Talanta.

Wallington, T.J., Nielsen, O.J., Novel method for the measurement of gas phase peroxy radical absorption spectra. – J. Phys. Chem.

Wallington, T.J., Ball, J.C., Nielsen, O.J., Bart-kiewicz, E., Spectroscopic, kinetic and mechanistic study of CH_2FO_2 radicals in the gas phase at 298K. – J. Phys. Chem.

11 Education

11.1 Ph.D. Theses

Andersson, K.G., 1991. Contamination and decontamination of urban areas. – Ph.D. Thesis, 94 p. Technical University of Denmark.

Bertelsen, F., 1991. Denitrifikation og bælgplantedyrkning (Denitrification and the cultivation of legumes). – Ph.D. Thesis, 72 p.

Ellermann, T., 1991. "Atmospheric CCl_3 Degradation", Ph.D. Thesis, Roskilde University Center.

Nielsen, K.A., 1991. Establishment and biochemical characterization of embryogenic cell suspensions of barley (*Hordeum vulgare* L.) – Ph.D. Thesis, Riso National Laboratory and Aarhus University, 86 p.

Møller, S., 1991. Sensitized triplet E/Z Photoisomerization of 1,3,5-hexatriene and 2,5-dimethyl-1,3,5-hexatriene. – Ph.D. Thesis, Roskilde University Center.

11.2 M.Sc. Theses

Jacobsen, F., Kjærsgaard, U., Hansen, T. M., 1991. Ozonolysis of ascorbic acid. (in Danish) Roskilde University Center, Roskilde.

Johansson, A., 1991. Kloning og sekventering af en frøspecifik bygperoxidase BP 1. (in Danish) University of Copenhagen, 75 p.

Justesen, A.F., 1991. Restriction Fragment Length Polymorphism og Random Amplified Polymorphic DNA som markører til kortlægningsbaseret kloning i *Erysiphe graminis* f.sp. *hordei*. Royal Veterinary and Agricultural University, Copenhagen, 88 p.

Rasmussen, H. Nørgaard, 1991. Oprensning og sekventering af peroxidase cDNA-kloner fra bygblade (in Danish). Technical University of Denmark, 104 p.

11.3 Contribution to Scientific Cources

Aarkrog, A., Dahlgaard, H., Hansen H.J.M., Nielsen, S. P., Nordic postgraduate course on Radioecology, Lund University, April 1991 (NKS/RAD). Four lectures: Source Terms and Inventories of Antropogenic Radionuclides, Statistical Treatment of Data, Marine Radioecology, Compartmental Modelling in Radioecology.

Aarkrog, A., Lectures presented at the Workshop on Environmental Impact Assessment in NPP Siting. Djakarta, Indonesia, September 23 – October 4, 1991.

12 Exchange of Scientists

Ahmed, Dr. S., ECC Fellowship, NCD Pinstech, Nilore, Islambad, Pakistan (1 year).

Anastasi, Dr. C., University of York, England (1 week).

Bajdor, Dr. K., Industrial Chemistry Research Institute, Poland (3 months).

Bartkiewicz, M.Sc. E., Agricultural and Teachers University, Siedlce, Poland (6 months).

Brobrowski, Dr. K., Polish Academy of Sciences, Poland (4 weeks).

Burlinska, Dr. G., Institute of Nuclear Chemistry and Technology, Warszawa, Poland (2 weeks).

Burns, Dr. D., National Physical Laboratory, Teddington, UK (1 week).

Byrne, M., Imperial College, London, England (4 weeks).

Christensen, Prof. H., Studsvik Energiteknik AB, Sweden (4 weeks).

Christiansen, S. K., visiting scientist at Department of Plant Pathology, Cornell University, Ithaca, New York 14850, USA (1 year).

Chung, Dr. W.H., Pusan National University, Korea (2 weeks).

Dahlan, Dr. K.Z. Hj. M., Nuclear Energy Unit, Kajang, Malaysia (2 weeks).

Getoff, Prof. N., University of Vienna, Austria (1 month).

Hart, Dr. E.J., Port Angeles, USA (4 weeks).

Hickel, Dr. B., CNRS, Saclay, France (2 weeks).

Ikram, Dr. A., Microbiol. Division, The Rubber Research Institute of Malaysia (RRIM) (6 months).

Jochimsen, lektor, B.U., Aarhus University, Denmark (1 year).

Joner, Stud.dr.scient., E., Agricultural University of Norway (4 months).

Jowko, Dr. A., Agricultural and Teachers Univer-sity, Siedlce, Poland (1 week).

Kläning, Dr. U., Århus University, Denmark (4 weeks).

Korotkov, A., Institute of Biology of the Southern Seas, SSR. Sevastopol, USSR (2 months).

McLaughlin, Dr. W.L., National Institute of Standards and Technology, Gaithersburg MD, USA (2 weeks).

Marthe, F., Institut für Genetik und Kulturpflanzenforschung, Gatersleben, Germany (2 weeks).

Mordzinski, Dr. A., Polish Academy of Sciences, Poland (2 weeks).

Nath, Dr. B. Nagender, National Institute of Oceanography, India

Orlandi, Prof. G., University of Bologna, Italy (1 week).

Pearson, Dr. J.N., School of Agriculture, The University of Western Australia, Perth (4 months).

Pikaev, Prof. A.K., Institute of Physical Chemistry, Academy of Science, Moscow, Russia (2 weeks).

Ratajczak, Dr. E., University of Wroclaw, Poland (1 month).

Sharpe, Dr. P., National Physical Laboratory, Teddington, UK (1 week).

Sidebottom, Dr. H., Univerisity College Dublin, Ireland (2 weeks).

Simpson, Dr. V.J., University of York, England (1 week).

Solar, Prof. S., University of Vienna, Austria (1 month).

Szaloki, Dr. I., Debrecen, Hungary.

Ten Wolde, A., University of Leiden, The Nether-lands (1 month).

Thiele, V., Institut für Pflanzenzüchtung, Gülzow, Germany (2 weeks).

Wallington, Dr. T., Ford Motor Co., Dearborn, USA (2 weeks).

13 Cooperative Projects

Radioactive tracers in the Greenland Sea. Part of the international Greenland Sea Project. *H. Dahlgaard.*

Studies on the Transport of Coastal Water from the English Channel to the Baltic Sea using Radioactive Tracers. Marine Science and Technology Programme (MAST), CEC. Cooperative projekt including Riso National Laboratory; Federal Maritime and Hydrographic Agency, Germany (Formerly DHI): Netherlands Energy Research Foundation: Commissariat a l'Energie Atomic, France: Ministry of Agriculture, Fisheries and Food, Lowestoft, UK. Project coordinator. 1990-1993. *H. Dahlgaard, S.P. Nielsen.*

Nordic Radioecology Cooperation (NKS/RAD). RAD1 - Education, Quality Assurance, Methodology; RAD2 - Aquatic Radioecology; RAD3 - Agricultural Ecosystems; RAD4 - Natural Ecosystems. *A. Aarkrog, H. Dahlgaard, S.P. Nielsen.*

Radioecology of seminatural ecosystems (CEC). Cooperative project including Riso National Laboratory, (DK), Nuclear Energy Board (IR) (Coordination), Institute of Terrestrial Ecology, Merlewood (UK), Swedish University of Agricultural Science, Uppsala (S), University of Thessaloniki (G). *A. Aarkrog, S.P. Nielsen.*

Riso's integrated environmental project (RIMI). *O.J. Nielsen, T. Nielsen, K. Pilegaard, P. Solgaard.*

Uptake of Nitrogen compounds by above ground plant parts. Collaborator: National Environmental Research Institute DK. *K. Pilegaard.*

Biological monitoring of heavy metals. Collaborator: Laboratory of Environmental Research Institute. Science and Education, The Technical University, Lyngby. *K. Pilegaard.*

EUROTRAC-BIATEX. Biosphere/Atmosphere Exchange of Pollutants. *K. Pilegaard.*

EC-project on Deposition in Urban Areas. Collaborators: UKAEA, Harwell, GSF, Münich. *J. Roed.*

EC-Sovjet Project on Countermeasures. CHECIR, Ukraine. *J. Roed.*

EC-project on Urban Decontamination. Collaborators: UKAEA, Harwell, Catholic University, Leuven, Glasgow University. *J. Roed.*

EC-project on Indoor Deposition. Collalborator: Imperial College, London. *J. Roed.*

F -project on Weathering and Resuspension. Collaborators: UKAEA, Colchester, GSF, Münich. *J. Roed.*

EC-project on Development of Skim and Burial Plough. Part of RESSAC; Main Collaborator: Cadarache, France. *J. Roed.*

NKA-project on Waste Created by Clean Up of an Urban Area. Collaborators: Helsinki University, Agricultural University, Oslo, SSI, Sweden. *J. Roed.*

IAEA Project on Validation of Model Parameters VAMP. *J. Roed.*

Cesium sulphate processes from pollucit. *K. Nilsson.*

EFP-project on temperature-time variations in North Central Trough sediments by fission track analyses of selected drill cores. Collaborators: University of Copenhagen and DMU. *H. Kunzendorf.*

SNF-project on Cretaceous-Tertiary boundary studies by Copenhagen University. *H. Kunzendorf.*

Trace element studies in sediments from the Skagerak–Kattegat area. Collaborators: Geological Survey of Denmark and University of Gothenborg, Sweden. *H. Kunzendorf, P. Solgaard.*

Baltic Marine Cooperation. Marine environmental studies in the Baltic Sea. Collaborators: Roskilde University Center and Danish Road Laboratory. *H. Kunzendorf.*

Geochemistry studies of marine ferromanganese phases. Collaborators: University of Kiel, New Zealand Oceanographic Institute and National Institute of Oceanography, India. *H. Kunzendorf.*

Development and application of instrumental analytical techniques for application in geochemistry. Collaborator: Tracechem, Copenhagen. *H. Kunzendorf.*

EUROTRAC–TOR. Tropospheric ozone research. Danish collaborator: National Environmental Research Institute. *T. Nielsen.*

Riso's integrated environmental project (RIMI). *T. Nielsen, P. Solgaard.*

DCAR–Traffic–PAH project. Collaborators: National Environmental Research Institute, Institute of Toxicology, dk–Teknik and Kobenhavns Kommunes Miljokontrol. *T. Nielsen, P. Solgaard.*

CEC Community Bureau of Reference Intercomparison of trace elements in lichen. *P. Solgaard.*

FLAIR Concerted Action No 10. The Measurement of Micronutrient Absorption and Status. *P. Solgaard.*

Treatment of wastes. Collaborators: NKT Research Center and Canadian Occidental. *E. Sørensen, A.B. Bjerre.*

Geochemical databases. A joint CEC project within the CHEMVAL group. *B. Skytte Jensen.*

Geochemical Modelling. The JENSEN geochemical computer program. A joint CEC project within the MIRAGE group. *B. Skytte Jensen.*

LITTLE JOE. An expert system to support geochemical modelling. A joint CEC project within the MIRAGE group. *B. Skytte Jensen.*

Colloid Behaviour. A joint CEC project within the MIRAGE group. *B. Skytte Jensen.*

Uncertainties in the Modelling of Migration Phenomena. A joint CEC project within the MIRAGE group. *B. Skytte Jensen.*

MODECS. Molecular Design of Chemical System. An R&D–forum for industries and institutions interested in the mentioned topic. *B. Skytte Jensen.*

EC–project on Atmospheric chemistry of halogenated compounds. 9 European laboratories. *O.J. Nielsen.*

EC–Project on Atmospheric Chemistry of Organic Sulfur and Nitrogen Containing Compounds. *O.J. Nielsen.*

EUROTRAC–LACTOZ, Laboratory Studies of Chemistry Related to Tropospheric Ozone. *O.J. Nielsen.*

Ford Motor Company collaborative project on CFC substitutes, *O.J. Nielsen.*

NATO Collaborative Research Grant Denmark. G. Orlandi, Italy. A.M. Brouwer, H.J.C. Jacobs, J. Lugtenburg, The Netherlands. *R. Wilbrandt,* Denmark.

Investigation of MOLSWITCH compounds. CISMI. Collaborator: K. Bechgaard, University of Copenhagen. *R. Wilbrandt.*

Danish Natural Science Research Council, project on the characterization of potential energy surfaces of molecules and radicals. Collaborators: F.W. Langkilde, Royal Danish School of Pharmacy, O.S. Mortensen, Odense University. *R. Wilbrandt.*

Danish Natural Science Research Council, project on atmospheric chemistry. Collaborators: Copenhagen University and National Environmental Research Institute. *O.J. Nielsen.*

Risø's integrated environmental project (RIMI). *O.J. Nielsen, T. Nielsen, P. Solgaard.*

Euromet. Collaboration with National Physical Laboratory, UK on calibration and measurements of ionizing radiation. *A. Miller.*

IAEA. Research agreement no 6919: Reference dosimetry for industrial Electron Accelerators. *A. Miller.*

IAEA. Research agreement no 6612: Methods for measurement of absorbed dose and dose distribution at 200–1000 keV electron beams. *A. Miller.*

Assessment of air pollutant effects on growth, quality and metabolism of agricultural crops. Subcontract to NERI EEC collaboration. *K.C. Engvild.*

Mikrobielle processer i rodzonen i relation til planternes forsyning med næringsstoffer 1988–1991 (Microbial processes in the root zone in relation to supply of plants with nutrients). Collaborators: Seven Danish research laboratories. *I. Jakobsen, A. Johansen.*

Carbon drain and phosphorus transport by VA-mycorrhizal fungi. Collaborators: L.K. Abbott and J.N. Pearson, The University of Western Australia. *I. Jakobsen.*

Evaluating the role of legume cover crops in the nitrogen nutrition of rubber 1989–1993. CE project under The International Scientific Co-operation Programme. Collaborator: The Rubber Research Institute of Malaysia, Kuala Lumpur. *I. Jakobsen, E.S. Jensen.*

Kombineret halmnedmuldning og efterafgrodedyrkning 1989–1992 (Combined straw incorporation and cultivation of catch crops 1989–1992). Collaborators: I. Thomsen and B. T. Christensen, Government Research Station Askov, Danish Research Service for Plant and Soil Science. *E.S. Jensen.*

Nutritional therapy of patients with livercirrhosis 1990–1992. Collaborator: K. Nielsen, Medical Department A. Rigshospitalet, Copenhagen. *E.S. Jensen.*

Exchange of metabolites across the peribacteroid membrane in legume root nodules 1989–1992. Collaborators: M.J. Dilworth and A.R. Glenn, Murdoch University, Western Australia. *L. Rosendahl.*

Compound exchange in symbiotic nitrogen fixation. Collaborator: B.U. Jochimsen, University of Aarhus. *L. Rosendahl.*

Interaction between different crop plants and weeds. Collaborator: B. Sogaard, The Royal Veterinary and Agricultural University. *H. Doll.*

Efficiency of partial mildew resistance in barley and correlation with secondary metabolites in the leaves. Collaborator: B. Sogaard, The Royal Veterinary and Agricultural University. *H. Doll.*

Linkage map of the barley genome. Collaborators: The Royal Veterinary and Agricultural University; the Danish plant breeding stations: Abed, Sejet, Pajbjerg; European and American barley geneticists. *H. Giese, J. Jensen, L. Petersen, S. Rasmussen.*

Molecular genetics of *Erysiphe graminis* f.sp. *hordei*, the causal agent of barley powdery mildew. Collaborators: Danish Plant biotechnology Research Center; The Royal Veterinary and Agricultural University; J. McDermott, ETH Zentrum, Zurich. *H. Giese, M. Lyngkjær, L. Borbye, M. Rasmussen.*

Genetic variation between cotton varieties. Collaborator: The Royal Veterinary and Agricultural University. *H. Giese, B. Kolling.*

Genetic markers for embryogenesis in barley. Collaborators: University of Copenhagen; D.

Bowles, Leeds University, U.K. *H. Giese, E. T. Larsen.*

QTLs (Quantitative Trait Loci) in barley. Collaborator: The Royal Veterinary and Agricultural University. *J. Jensen, B. Kjær.*

Improvement of protein quality in barley. Collaborator: B.O. Eggum, Foulum Research Station. *J. Jensen, S. Rasmussen.*

Evaluering af korn i Nordisk Genbank, 1990- (Evaluation of cereal genetic sources in the Nordic Gene Bank, 1990-). Collaborators: Nordic Gene Bank, Alnarp, and Svalöf AB, Sweden; Hankkija, Finland. *J.H. Jorgensen.*

Ny meldugresistens i byg, 1989- (New sources of powdery mildew resistance genes in barley, 1989-). Collaborators: Three Danish cereal breeding companies. *J.H. Jorgensen, H.P. Jensen.*

Risk assessment of genetically modified plants. Collaborators: A. Buchter-Larsen, Danisco Maribo Division; J. Fredshavn, The Royal Veterinary and Agricultural University; S. Mark, National Forest and Nature Agency. *R.B. Jorgensen.*

Recombination estimates and physical/chemical distances on the chromosomes. Collaborator: The Royal Veterinary and Agricultural University. *I. Linde-Laursen, H. Giese, C. Pedersen.*

Polyploid *Hordeum* species. Collaborators: R. von Bothmer, Department of Crop Genetics and Breeding, The Swedish University of Agricultural Sciences, Svalöv, Sweden. *I. Linde-Laursen.*

Callose synthesis in barley. Collaborators: J. Hejgård and S. Jacobsen, Danish Technical University. *S.K. Rasmussen, L.H. Pedersen.*

Barley peroxidases. Collaborators: Aarhus University; Danish Plant Biotechnology Programme. *S.K. Rasmussen, B. Theilade.*

Genetics of resistance to barley leaf stripe. Collaborator: B.J. Nielsen, Plant Protection Institute, Lyngby. *J.P. Skou, V. Haahr.*

Linkage map of Norway spruce. Collaborator: H. Wellendorf, The Arboretum, Horsholm. *E. Skov, H. Giese.*

Population dynamics of *Erysiphe graminis* f.sp. *hordei*. Collaborators: M. Hovmoller, Research Centre for Plant Protection, and L. Munk, The Royal Veterinary and Agricultural University. *H. Østergård.*

14 Guest Lectures

Professor T. Bally, University of Fribourg, Switzerland: "Vibrational structure of organic radical cations: A systematical approach".

Dr D. Dennis, Edinburgh Instruments, Edinburgh, UK: "Fluorescence lifetime spectroscopy".

Dr P. Devolder, Laboratoire de Cinétique et Chemie de la Combustion, Université de Lille, France: "Tropospheric oxidation of aromatics: Reactions of a few benzyl type radicals with O_2 and NO_x".

Dr A. Grabowska, Institute of Physical Chemistry of the Polish Academy of Sciences, Warsaw, Poland: "Single and double intramolecular proton transfer processes in heteroaromatics excited to the S_1 and T ates".

P. Hofvander, Svalöf AB, Sweden: "Use of antisense RNA changing starch of potatoes".

S. Kannaiyan, King's College, London: "Nitrogen fixing potential of the Azolla-Anabaena complex and their utilization as biofertilizers for rice".

Dr T. Konishi, Institute of Genetic Resources, Faculty of Agriculture, Kyushu University, Japan: "Application of Isozyme Technology to Barley Breeding".

Dr R.B. Mellor, Botanisches Institut der Universität Basel: "Plant reactions to endosymbiosis at the molecular and organelle level".

Drs M. Micke and V. Thiele, Institut für Pflanzenzüchtung, Gülzow, Mecklenburg, Germany: "Transfer of resistance gene from *Hordeum bulbosum* to barley varieties".

I.M. Møller, Department of Plant Physiology, University of Lund, Sweden: "Plant Mitochondria".

N. Pearson, Department of Soil Science, University of Western Australia: "Competition between mycorrhizal fungi".

Professor A.K. Pikaev, Institute of Physical Chemistry of the USSR Academy of Sciences, Moscow, USSR: "Radiation processing and related dosimetry in the USSR".

P. Steen, Maribo Seeds, Denmark: "Experience with genespliced sugar beets in field experiments".

U. Sochting, Institute of Spore Plants, University of Copenhagen: "Biological monitoring of nitrogen deposition by means of lichen".

Dr M.H. Thiemens, Department of Chemistry, U.C. San Diego, La Jolla, USA: "New isotope effects: Application to atmospheric chemistry, chemicals physics and the origin of the solar system".

P. Ulvskov, Institute of Plant Biology, The Royal Veterinary and Agricultural University: "Regulation of elongation growth in pea".

Dr C. Zetzsch, Frauhofer Institut, Hannover, Germany: "Photochemical degradation of aromatics by OH in the troposphere: Detailed investigation of the mechanism".

15 Committee Memberships

15.1 National

Aarkrog, A. Danish Contact Forum for Health Physics.
Danish National Council for Oceanology.
Danish reference group for CEC's MAST programme.
Danish reference group for CEC's Radiation protection programme.

Andersen, A.J. Member of the board of Pajbjergfonden.

Dahlgaard, H. Greenland Sea Project, Danish working group.

Giese, H. Member of The Danish Agricultural and Veterinary Research Council.
Member of the board of The Institute of Farm Management.
Danish Society for the Conservation of Nature, Committee for Environmental Issues.

Gissel-Nielsen, G. Vice chairman of The Danish Agricultural and Veterinary Research Council.
Member of the board of the Danish Academy of Technical Sciences.
Member of the board of the National Research Service for Soil and Plant Sciences.
Danish Society for the Conservation of Nature, Committee for Environmental Issues.

Jørgensen, J.H. Dansk Genbanknævn.
Koordineringsgruppen for resistens og virulens i korn og kornsygdomme.

Miller, A. Danish Utensil Producer Organisation (DUFO). Sterilization committee.

Nielsen, O.J. The National Committee for The International Geosphere-Biosphere Programme (IGBP).

Pilegaard, K. Danish Centre for Atmospheric Research (DCAR) Working Group on effects. (Chairman).

Solgaard, P. Dansk Standardiserings Råd.
S168-Vandundersogelse, FaU 213

15.2 International

Aarkrog, A. IAEA CRP MARDOS. (Chairman).
IAEA VAMP programme. (Consultant).
CGC for CEC's Radiation Protection Programme.
Reference group NKS-RAD Programme.
Group to evaluate the Research Programme on Radioactive Fallout of the Norwegian Agricultural Research Counsil.
Editorial Board of J. Environ. Radioactivity.

Dahlgaard, H. Baltic Marine Environment Protection Commission, Helsinki Commission (HELCOM). Group of Experts on Monitoring of Radioactive Substances in the Baltic Sea (MORS) Marine Radioecology Working Group (MARECO), International Union of Radioecologists (IUR). (Working Group Leader).
Working Group on a Nordic participation in the World Ocean Circulation Experiment. (WOCE)
Nordic Nuclear Safety Project (NKS), Radioecology programme (RAD). (Coordinator).

Engvild, K.C. Member of Journal Committee of 'Physiologia Plantarum'.

Gissel-Nielsen, G. OECD committee for plant/soil/microbial interactions.

Jakobsen, I. Management committee for COST Action 810: The role of VA-mycorrhizae in transformation of matter in the soil and their importance for plant nutrition and plant health.

Jensen, E.S. Editorial Board of 'Plant and Soil'. Sectionboard for Soils and Fertilizers, Scandinavian Association of Agricultural Scientists.

Jensen, J. International coordinator, barley chromosome 5; International Barley Nomenclature Committee.

Jens B. Skytte. Working Groups within the EEC R&D Programme Management and Storage of Radioactive Waste (MIRAGE), in the subcommittés CHEMVAL, COCO, and Natural Analogues.
Member of WP Geological Disposal of Radioactive Waste. The Editorial Board of "Waste Management".

Jørgensen, J.H. Editorial board of 'Euphytica'.
International coordinator, disease and pest resistance genes.
Working group on cereal disease resistance biology, Scandinavian Association of Agricultural Scientists.
Working group cereal, Nordic Gene Bank. (Chairman).
Working group barley, European Coordinated Programme Genetic Resources.
Coordinating Committee. International Barley Genetics Resources Network.

Kunzendorf, H. Editorial Board of 'Marine Mining'.
Member of the Board of the 'International Marine Minerals Society'.
Member of the planning group for a new Technologic Center for Marine Minerals.
Reviewer of Marine Chemistry, Marine Geology, Marine Mining, Mineralium Deposita.

Linde-Laursen, I. Editorial Board of Plant Systematics and Evolution.

Miller, A. American Society for Testing and Materials: Subcommittee E10.01: Dosimetry for Radiation Processing.
Editorial Board of Radiation Physics and Chemistry (Pergamon Press).
Editorial Board of Radiation Sterilization (Israel).
Programme Committee, Int. Meeting on Radiation Processing, Beijing, 1992. Committee. Science Council, Beta Tech AB, Jönköping, Sweden.

Nielsen, O.J. COST-611 Concertation Committee on Physico-Chemical Behaviour of Atmospheric Pollutants.
COST-611 Working Party 2 Steering Committee, Atmospheric and Photochemical Processes.

Nielsen, T. The board of Nordic Society of Aero-sols (NOSA).

Nielsen, S.P. International Committee on Radionuclide Metrology.
Articles 35 and 36 of the Euratom Treaty (Environmental Monitoring).

Roed, J. The Group on in-situ measurements (ICRU).
IAEA and EEC VAMP Project Urban Group. (Chairman).
The Fuel Cycle Safety Group (OECD).
SCOPE RADPATH.

Skou, J.P. Section for Plant Protection (Chairman), Scandinavian Association of Agricultural Scientists.

Wilbrandt, R. International Organization Committee on the Conference of Time-resolved Vibrational Spectroscopy, Tokyo, Japan.
International Organization Committee on the Conference on the Spectroscopy of Biological Molecules, York, England.

16 Seminars Organized

COST 810 workshop, "The Use of ^{15}N Methodology in Studies on the ROLE OF VA-Mycorrhizas in N Cycling", December 5-6, 1991 (*I. Jacobsen*).

RFLP course for Danish Plant Breeders. Section of Plant Biology, December 2-5, 1991 (*Henriette Giese*).

Danish Biochemical Society meeting: Enzymes in Plant Pathogen Resistance, March 12, 1991. (*Søren Rasmussen*).

17 Personnel

The list also include short term employees

Head of Department
Arne Jensen

17.1 Scientific Staff

Aarkrog, Asker
Andersen, Arna J.
Berenstein, Dvora
Bjergbakke, Erling
Bjerre, Anne Belinda
Christiansen, Solveig Krogh
Dahlgaard, Henning
Doll, Hans
Ellermann, Thomas
Engvild, Kjeld C.
Fenger, Jorgen
Giese, Henriette
Gissel Nielsen, Gunnar
Gundersen, Vagn
Haahr, Vagner
Hansen, Heinz J.M.
Hansen, Knud B.
Holcman, Jerzy
Holme, Inger
Jakobsen, Iver
Jensen, Jens
Jensen, Hans Peter
Jensen, Erik Steen
Jensen, Bror Skytte
Jorgensen, Jorgen Helms
Jorgensen, Rikke Bagger
Kläning, Ulrik
Koie, Bertel
Kunzendorf, Helmer
Larsen, Else Toftdahl
Linde-Laursen, Ib
Lynggård, Bent
Mathiassen, Henrik
Miller, Arne
Nielsen, Sven P.
Nielsen, Ole John
Nielsen, Torben
Nilsson, Karen
Pagsberg, Palle
Pilegaard, Kim
Rasmussen, Soren
Roed, Jorn
Rosendahl, Lis
Sehested, Knud
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Skou, Jens Peder
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Sorensen, Emil
Wilbrandt, Robert
Östergård, Hanne

17.2 Tehnical Staff

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Bitsch, Gunnar
Brandstrup, Oda
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Clausen, Jytte Lene
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Djurdjevic, Stanko
Dyrgaard Jensen, Lone
Ebling, Elise
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Hansen, Elly
Hasselbalch, Finn
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Ibsen, Elly

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Jensen, Ellen Moller
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Larsen, Erik Engholm
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Nielsen, Jette Bruun
Nielsen, Vagn Aage
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Vinther, Niels
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17.3 Office Staff

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Nielsen, Margit
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17.4 Ph.D. Students

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Olsen, Allan Gylling
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17.5 M.Sc. Students

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Jacobsen, Frank

Kjærsgaard, Ulrik
Suhr, Marianne
Thomsen, Susanne Brun

17.6. Apprentices

Hansen, Dorthe Thil
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Jensen, Christina Falk
Jensen, Ulrik Soby
Jensen, Thomas Nygaard
Jensen, Ulla Damm
Lauritzen, Lisbeth
Oreskov, Sisse
Tung, Tran Duc
Jensen, Lene
Korgaard, Charlotte

18 Acronyms

AA:	Atomic Absorption
BIOMOVS:	Biospheric Model Validation Study
BMC:	Baltic Marine Cooperation
BNN:	Bureau National de Métrologie
CEC:	Commission of European Communities
CGC:	Management and Coordination Advisory Committee
CRESP:	Coordinated Research and Environmental Surveillance Programme (under NEA)
DCAR:	Danish Centre for Atmospheric Research
DH:	Chromosome-Doubled Haploid
DKD:	Deutscher Kalibrierdienst
DIA:	Denmarks Academy for Engineering
DNA:	Dioxyribonucleicacid
DOAS:	Differential Optical Absorption Spectroscopy
DTH:	Technical University of Denmark
EC:	European Communities
EDX:	Energy dispersion X-ray fluorescence spectrometry
EEC:	European Economic Communities
ETV:	Electrothermal Vaporisator
EUROTRAC:	European Experiment on Transport and Transformation of Environmental Relevant Trace Constituents of Anthropogenic and Natural Origin
FATE:	Formation of Aerosol and their Transformation over Europe (under EUROTRAC)
FLAIR:	Measurement of Micronutrient Absorption and Status
GMP:	Genetically Modified Plants
GRECA:	Group of Experts on accident Consequences (under NEA, OECD)
GSF:	Gesellschaft für Strahlen - und Umweltforschung
GSP:	Greenland Sea Project
HELCOM:	Helsinki Commission
HDRL:	High Dose Reference Laboratory
IAEA:	International Atomic Energy Agency
IBSS:	Institute of Biology of the Southern Seas (USSR)
IC:	Ionchromatography
ICP/MS:	Inductively Coupled Plasma Mass Spectromety
ICARDA:	International Center for Agricultural Research in the Dry Areas
ICRM:	International Commitee on Radionuclide Metrology
ICRU:	International Commission on Radiological Units
IFE:	Institute for Energy Technology Norway
IUR:	International Union of Radioecologists
IVL:	Swedish Environmental Research Institute
MARDOS:	IAEA CRP on "Sources of Radioactivity in the Marine Environment and their Relative Contributors to Overall Dose Assessment from Marine Radioactivity"
MARECO:	Marine Radioecology Working Group (under IUR)
MARIA:	Methods for Assessing the Radiological Impact of Accidents. (Research programme under CEC)
MAST:	Marine Science and Technology Programme (under CEC)
MODECS:	Molecular Design of Chemical Systems
MORS:	Group of Experts Monitoring of Radioactive Substances in the Baltic Sea
NAMAS:	National Measurement Accreditation Service
NEA:	Nuclear Energy Agency (under OECD)

NERI:	National Environmental Research Institute
NGB:	Nordic Gene Bank
NKA:	Nordic Liason Committee for Atomic Energy
NKO:	Nederlandse Kalibratie Organisatie
NKS:	Nordic Nuclear Safety Project
NLVF:	Norway Agricultural Research Council
NZOI:	New Zealand Oceanographic Institute
OECD:	Organisation for Economic Cooperation and Development
PAH:	Poly Aromatic Hydrocarbons
PBM:	Peribac eroid Membrane
PBU:	Peribacteroid Unit
PCR:	Polymerase Chain Technologi
PMC:	Pollen Mother Cell
QTL:	Quantitative Trait Loci
RAD:	Radioecology Programme (under NKS)
RAPD:	Random Amplified Polymorphic DNA Technique
RADPATH:	Biochemical Pathways of Artificial Radionuclides (under CEC)
RESSAC:	The Consequence of a Major Nuclear Accident on the Surrounding Environment: Soil and Surface Rehabilitation (under CEC)
RFLP:	Restriction Fragment Length Polymorphism
RIMI:	Riso Intergrated Environmental Project
RUC:	Roskilde University Center
RVAU:	The Royal Veterinary and Agricultural University
SCOPE:	Scientific Committee on Problems of the Environment (under International Council of Scientific Unions: (ICSU))
SCS:	Swiss Calibration Service
SIT:	Servizio di Taratura in Italia
SJVF:	Veterinary Agricultural Research Council
SWEDAC:	Swedish Board for Technical Accreditation
TOR:	Tropospheric Ozone Research (under EUROTRAC)
UKAEA:	United Kingdom Atomic Energy Authorities
VAM:	Vesicular-Arbuscular Mycorrhiza
VAMP:	Validation of Model Project (under IAEA)
WECC:	Western European Calibration Cooperation
WOCE:	World Ocean Circulation Experiment

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Abstract (Max. 2000 characters)

Selected activities in the Environmental Science and Technology Department during 1991 are presented. The research approach in the department is predominantly experimental. The research topics emphasized are introduced and reviewed in chapters one to seven: 1. Introduction, 2. The Atmosphere, 3. Plant Genetics and Resistance Biology, 4. Plant Nutrition, 5. Geochemistry, 6. Ecology, 7. Other activities. The Department's contribution to national and international collaborative research programmes is presented together with information about large facilities managed and used by the department. Information about the department's education and training activities are included in the annual report along with lists of publications, publications in press, lectures and poster presentations. Further, names of the scientific and technical staff members, Ph.D. students and visitiing scientists are listed.

Descriptors INIS/EDB

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